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Mobile Information Systems Impact Study

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Mobile Information Systems Impact Study

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16. Résumé

Ce rapport fait un tour d'horizon des techniques et matériels de guidage routier embarqué et de communications mobiles. Il classe les matériels au moyen d'une matrice de caractéristiques parmi lesquelles figurent: infrastructure, filière de guidage embarqué, fonctions du système, etc. La question de l'adaptation ergonomique y est également traitée.

Les fonctions principales susceptibles d'être assurées par les systèmes à l'étude (affichage électronique de cartes routières, avis sur les conditions de circulation, localisation et suivi des véhicules et cargaisons) ainsi que les caractéristiques correspondantes sont répertoriées dans cinq champs d'application: radioguidage routier, gestion de parcs automobiles, gestion de la circulation, bureaux mobiles, activités des occupants et contrôle des véhicules.

Les débouchés possibles et les fournisseurs canadiens de matériels et logiciels sont recensés dans le but de donner une idée des marchés futurs. Le rapport propose également des résumés des programmes de recherche et développement en cours à l'étranger. Il aborde l'élaboration de normes et règlements applicables au domaine considéré, en plus de proposer des normes préliminaires concernant les interfaces homme-machine en vue de garantir la sûreté d'utilisation des divers matériels en question.

Enfin, le rapport cerne les besoins de R&D et d'expérimentation et propose sept projets prioritaires visant à accélérer l'étude et la réalisation de systèmes canadiens et à dégager les moyens de promouvoir une utilisation accentuée de ces technologies.

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EXECUTIVE SUMMARY

Except for some very early developments in China - the 'South Pointing Carriage' around 200 A.D. and the magnetic compass 1000 years later - and a brief flurry of activity during the early days of the automobile and again during World War II, there were few advances in land navigation until the late 1960s. At that time, several concepts for providing electronic route guidance were developed; however, these systems did not progress beyond experimental stage because the required technology was still too expensive and unreliable for widespread application.

Recent advances in micro-electronics, however, have helped generate renewed interest in vehicle positioning, navigation and route guidance systems. The fact that these systems, if adapted to traffic and fleet management, could help alleviate urban traffic congestion and increase the efficiency of transporting goods and providing other services, has added a sense of urgency to their development.

This report contains a **state-of-the-art review** of those mobile information systems which can display vehicle position relative to a map data base and which facilitate or perform navigation and route guidance functions. In-vehicle navigation and communications technologies, components of representative systems and methods of digitizing and storing map data are described. Thirty-nine mobile systems, demonstrated or announced in the 1980s, are classified by their infrastructure relationship, navigation technique and available functions, map format and storage, output/input methods and potential applications.

It is too early to predict which technologies and types of systems will eventually gain widespread acceptance: autonomous dead-reckoning supplemented with map matching, or navigation systems based on proximity devices, ground-based radio signals or satellites. Perhaps in realization of the present shortcomings of each of these systems, many system concepts

incorporate two, even three, positioning technologies.

Human factors considerations are presented from the perspective of the 'human information processor', which is highly susceptible to error when overloaded. It is emphasized how limited we are in our ability to acquire and process external visual information (needed for primary driving tasks) while attempting to perform in-vehicle tasks, such as reading a CRT map display. A design guide for in-vehicle electronic displays and controls specifies the primary factors to be considered: ergonomic principles and manner of installation, information types and content, presentation method and mode, display technology and controls, available support modules, and the intended application for the system.

A typical man-machine interface today includes symbolic graphics, alphanumeric messages and audio signals. However, there are still major differences in visual presentation of map information: simplified displays (skeleton maps or directional arrows) are preferred in Europe; a vectorized map on a monochrome CRT is offered in the U.S.; and, elaborate colour CRT map displays are popular in Japan.

Safety-in-use will have to be the primary consideration in the development of mobile information systems, and much work is yet to be done on the design, installation and use of these systems. Research should be undertaken to determine the amount of information that may be safely presented to the driver when the vehicle is in motion - depending on whether the driver is in a familiar or unfamiliar area, what the road and traffic conditions are, etc. Sound research is essential to ensure that these devices will enhance, rather than degrade, the overall safety of the driver/vehicle system.

A perspective on potential markets for mobile information systems includes the identification of their likely application areas, the expected benefits and the means of achieving these benefits. The primary functions likely to be provided in future sophisticated systems - eg. road map display, information on travel conditions and road side services,

vehicle and cargo position tracking and security, route guidance, emergency response, etc - and their specific features have been grouped under five application areas: *travel advisory*, *fleet management*, *traffic management*, *mobile office*, *occupant activities and vehicle/driver monitoring and control*. The interrelationships of the components (modules) of a sophisticated future mobile information system are presented in a functional block diagram.

Interviews of representatives of likely direct and indirect user communities determined that the current knowledge about mobile systems is very limited and that many barriers to their speedy adoption still exist. However, the enthusiasm of the potential users about the range of future system capabilities was almost uniform and provides an important further perspective on future market needs.

A preliminary list of possible **Canadian developers and suppliers** of hardware and software for mobile information systems and their components is presented. For the Canadian automotive and electronics industries and universities, only a small window of opportunity remains. They will have to get into the vehicle navigation/information systems field in a serious way now, or the Japanese, Europeans and Americans will surely take over the design, production and marketing of these systems. Any complacency on the part of Canadians will result in forgoing some unique industrial development and marketing opportunities.

Because of recent developments in micro-electronics, production cost seems to be the only limiting factor on the capabilities that can be incorporated into the navigation units. Further advances expected in the short term in data storage and particularly display technologies, such as high-speed graphics processors and heads-up displays, will make very sophisticated systems both technically and commercially feasible.

Care must be taken in assembling these hardware components into a safe-to-use, cost-effective package which, in all likelihood, will have to incorporate many functions currently

offered in, or planned for, the advanced vehicle control systems. An equally great challenge will be to develop applications software that makes the wide range of functions and features - required in order for these systems to be widely adopted - easy and safe to use.

Major **international and national programs** designed to accelerate the development of in-vehicle navigation/information systems have been established in Europe and Japan. In both cases, government agencies have assumed lead roles in financing and coordinating the co-operative programs together with the automotive and electronics industries and the university research communities. The United States, which had initiated the research into electronic driver aid and route guidance systems already in the 1960s (and then halted it), is beginning to follow suit through demonstration programs at both national and state levels.

This is in strict contrast to Canada, where no formal national strategy for advancing the research, development, demonstration, manufacturing and adaptation of mobile information systems technology has yet been formulated. There are many areas, beyond simple information dissemination, where the participation of government agencies would be highly complementary to private sector research and development initiatives.

To ensure that adequate **standards and regulations** are set <u>in advance of</u> the development and implementation of these systems, government's early action will be of critical importance. Preferred practises, uniform design criteria and official standards will need to be developed to cover on-board, roadside and central control equipment specifications, map data bases and their access software, as well as some common elements of applications software.

The report brings forth many of the primary issues in the development of standards and regulations and includes a detailed section on map standards and human factors. Preliminary man-machine interface design guidelines are recommended to

ensure safety-in-use of the in-vehicle positioning/navigation/route guidance/information/communications devices.

There are many unanswered questions which require **research, development and demonstration work** in the Canadian context. The report identifies seven priority projects that would significantly accelerate the design, testing and manufacturing of Canadian systems and would help identify opportunities for the increased use of these technologies. These are summarized with their primary objectives, as follows:

Highway Vehicle Electronics Project - to complete the state-of-the-art review for highway vehicle electronic technologies not covered under in-vehicle navigation and route guidance systems (focus of Phase I&II of this project).

Demonstration Project - to gather operational experience with an in-vehicle navigation/mobile communication system in a metropolitan operating environment.

Human Factors Studies - to investigate all critical man-machine interface issues related to the design, installation and use of mobile information systems to ensure that these devices will enhance, rather than degrade, the overall safety of the driver/vehicle system.

Market Survey - to undertake a mail and telephone survey of associations, and some of their prominent members, representing potential users of mobile information systems; and to undertake personal interviews of a small group of individual users.

Supplier Survey - to undertake a mail and telephone survey of current and potential Canadian suppliers of mobile information systems hardware and software components.

Information Dissemination Project - to inform potential users, suppliers and regulators of mobile information systems about the state-of-the-art of emerging technologies and of possible applications to which these systems may be adapted.

National Strategy Project - to develop a formal national strategy for advancing research, development, demonstration, manufacturing and application of mobile information systems in Canada.

Future mobile information systems will provide - in addition to positioning, navigation and route guidance - many capabilities which together will provide significant benefits to motorists. However, from the present Canadian perspective of trying to exploit promising industrial opportunities, some fundamental decisions will have to be made quickly if Canadians are to participate in a meaningful way in developing, designing and manufacturing these systems and in identifying opportunities for their increased use.

SOMMAIRE

A part quelques inventions apparues il y a longtemps en Chine - une version rudimentaire de l'odomètre différentiel actuel vers l'an 200 de notre ère et le compas magnétique quelque mille ans plus tard -- et de brefs regains d'intérêt lors de l'apparition de l'automobile, puis au cours de la Seconde Guerre mondiale, le guidage routier n'a pas connu beaucoup de progrès avant la fin des années 60. C'est à ce moment que les premiers systèmes électroniques de guidage routier ont vu le jour. Toutefois, ces systèmes n'ont jamais dépassé le stade expérimental, les technologies mises en oeuvre étant trop coûteuses et trop peu fiables pour permettre d'envisager un emploi généralisé.

Les plus récents progrès de la micro-électronique ont cependant fait ressurgir l'intérêt pour les systèmes de localisation de véhicules, de navigation et de guidage routier, intérêt d'autant plus marqué que l'adaptation de ces systèmes à la gestion du trafic routier et des parcs roulants pourrait soulager l'encombrement des réseaux routiers urbains et relever l'efficacité du transport routier et des services assimilés.

Le présent rapport recense les systèmes de communication mobiles actuels capables d'afficher à tout moment la position d'un véhicule sur une carte et de remplir, ou du moins de faciliter, certaines fonctions de navigation et de guidage routier. Il décrit divers systèmes embarqués de navigation et de communication et les éléments constitutifs de certains systèmes représentatifs ainsi que diverses techniques de numérisation et de stockage de données cartographiques. Trente-neuf systèmes embarqués dont la démonstration a été faite, ou qui ont été annoncés dans les années 80, sont classés suivant leur mode de communication sol-mobile, la technique de navigation mise en oeuvre et les fonctions qui les caractérisent, les techniques de stockage et de représentation des données cartographiques, les modes d'entrée et de sortie des données et les applications possibles.

Il est encore trop tôt pour prévoir lesquels parmi les systèmes et technologies recensées gagneront la faveur des intéressés: la navigation à l'estime complétée d'un système de repérage sur carte ou la navigation guidée par des dispositifs indicateurs de position relative, par des signaux radio émis depuis des installations au sol ou par satellite. Peut-être est-ce en raison des lacunes actuelles de chacune de ces technologies que plusieurs des systèmes mis au point font intervenir deux, et parfois trois, modes de localisation.

Les facteurs humains à prendre en compte sont considérés du point de vue du traitement de l'information; on sait par exemple que le cerveau est sujet à commettre des erreurs s'il est surchargé. Il est démontré combien l'aptitude du conducteur à percevoir et à comprendre les informations visuelles nécessaires à la conduite de son véhicule est limitée lorsqu'il s'attache à exécuter une autre tâche, comme vouloir saisir les informations cartographiques affichées à l'écran cathodique de bord. Un guide de conception d'équipements électroniques embarqués de communication et de visualisation précise les principaux facteurs à prendre en considération: principes ergonomiques, choix de l'information à donner et mode de présentation, module d'affichage et commandes, supports d'information disponibles et applications envisagées.

Dans l'état actuel d'avancement de la technologie, une interface homme-machine typique communique des informations sous forme de symboles graphiques, de textes alphanumériques ou de signaux sonores. La présentation visuelle d'informations cartographiques varie toutefois considérablement: en Europe, on préfère une présentation simplifiée (cartes schématiques ou flèches); aux Etats-Unis, ce sont les cartes avec flèches affichées sur écran monochrome, alors qu'au Japon, l'usage de cartes détaillées affichées sur écran polychrome est très répandu.

Les travaux concernant la conception et la réalisation des systèmes de communication mobiles, ainsi que la définition des applications possibles, sont loin d'être achevés et la sécurité en service de ces systèmes doit demeurer l'objectif premier. Il y aurait lieu d'entreprendre des recherches sur la quantité d'information qui peut être présentée au conducteur sans compromettre sa sécurité, selon que celui-ci se déplace dans un environnement familier ou nouveau, selon l'état de la chaussée, les conditions de circulation, etc. Il est essentiel de bien évaluer ce paramètre pour arriver à un gain, et non à une perte de sécurité routière.

Toute estimation du marché potentiel pour les systèmes de communication mobiles présuppose que les applications probables de cette nouvelle technologie soient d'abord définies, ainsi que les avantages qu'on peut espérer en tirer et les moyens à mettre en oeuvre pour y arriver. Les principales fonctions dont seront probablement dotés les systèmes sophistiqués de localisation, de navigation et de guidage routiers de demain (soit affichage de cartes routières, informations sur les conditions de la circulation et sur les installations et services le long de la route empruntée, localisation de véhicules ou de cargaisons, tracé d'itinéraires, communications de secours, etc.), ainsi que leurs caractéristiques particulières sont regroupées sous cinq domaines d'application: information routière, gestion des parcs roulants, régulation du trafic, bureaux mobiles, activités intéressant les occupants et contrôle du comportement du conducteur et du véhicule. Les divers modules que pourrait comprendre un système de communication embarqué sophistiqué sont représentés dans un schéma de principe.

Des entrevues menées auprès de représentants de divers groupes d'éventuels usagers directs ou indirects de systèmes de communication mobiles ont révélé que ces systèmes sont encore très peu connus et que de nombreux obstacles s'opposent encore à un usage répandu. Toutefois, l'enthousiasme général des personnes pressenties devant les multiples possibilités offertes par ces systèmes a permis de mieux évaluer la demande future.

On trouvera dans le rapport une liste préliminaire des éventuels constructeurs et fournisseurs canadiens de matériels et de logiciels aptes à équiper les systèmes envisagés. La place que peuvent encore occuper dans ce domaine les universités et les industries canadiennes de l'automobile et de l'électronique n'est plus très grande. Celles-ci devront se mettre sérieusement à la tâche si elles ne veulent pas être supplantées par les concepteurs, les constructeurs et les distributeurs japonais, européens et américains. Toute hésitation de la part des intérêts canadiens risque de les exclure de perspectives intéressantes dans les domaines du développement industriel et de la production commerciale.

Avec les derniers progrès de la micro-électronique, les caractéristiques dont peuvent être dotés les systèmes embarqués de navigation et de guidage routier ne sont plus limitées que par les coûts de production. Qui plus est, l'affinement des technologies de stockage et, en particulier, d'affichage de données (organes de traitement rapide de l'information graphique et systèmes de visualisation tête haute, par exemple) permettra dans un proche avenir de fabriquer et de mettre sur le marché des systèmes de communication mobiles très sophistiqués.

Les concepteurs sont placés devant deux défis de taille: d'une part, réunir dans un bloc à prix abordable et d'utilisation sécuritaire les matériels aptes à exécuter une bonne partie des fonctions dont sont déjà dotés les systèmes les plus perfectionnés de régulation routière, ou qui sont prévues pour un proche avenir; d'autre part, créer des logiciels d'application capables d'exécuter les fonctions susceptibles d'intéresser le plus grand nombre d'usagers, sans compromettre la facilité et la sécurité d'emploi.

Le Japon et l'Europe se sont dotés de programmes nationaux et internationaux en vue d'accélérer la mise au point de systèmes embarqués de navigation et de guidage routier. Dans les deux cas, les autorités publiques ont assumé un rôle prépondérant dans le financement et la coordination de ces programmes, menés de concert avec les industries de l'automobile et de l'électronique et les groupes de recherche universitaires. Les Etats-Unis qui avaient été les premiers à lancer, dès les années 60, des recherches sur l'assistance électronique à la conduite automobile et de guidage routier, pour ensuite les abandonner, suivent maintenant le Japon et les pays d'Europe de près avec des programmes de démonstration instaurés dans plusieurs Etats aussi bien qu'à l'échelle nationale.

Le Canada, au contraire, n'a adopté aucune stratégie pour promouvoir la recherche et la mise au point, la démonstration, la fabrication et l'adaptation de systèmes de communication mobiles. Il y a pourtant plusieurs secteurs, en dehors de la simple diffusion d'information, où les autorités publiques pourraient appuyer les efforts de recherche et de développement du secteur.

Il est essentiel que les autorités agissent sans tarder pour établir les normes et les règlements pertinents, c'est-à-dire avant même la mise au point et la mise en service des systèmes envisagés. Il faudra définir des critères de conception, établir des normes et formuler des recommandations pour tous les matériels, équipements et installations embarqués ou au sol, pour les bases de données cartographiques et les logiciels y donnant accès ainsi que pour certains éléments communs des logiciels d'application.

Le rapport fait ressortir les points principaux sur lesquels devront porter les normes et les règlements en cause et s'attache en particulier aux modes de présentation des données cartographiques et aux facteurs ergonomiques. Quelques lignes directrices préliminaires portant sur la conception de l'interface homme-machine sont formulées en vue de garantir la sécurité des systèmes envisagés.

Un grand nombre de questions demeurent sans réponse et devront faire l'objet de recherches, de travaux de mise au point et d'essais en contexte canadien. Le présent rapport définit sept projets qu'il y aurait intérêt à poursuivre en priorité pour accélérer la conception, la mise à l'essai et la fabrication de systèmes de communication mobiles canadiens et pour déterminer l'éventail des applications possibles de cette nouvelle technologie. Ils sont résumés ci-dessous.

Etude des technologies électroniques appliquées à l'automobile - Examiner les technologies électroniques adaptées à l'automobile, autres que les systèmes embarqués de navigation et de guidage routier étudiés dans les phases I et II du présent projet.

Projet de démonstration - Evaluer un système de communication embarqué dans un contexte urbain et péri-urbain défini.

Etude des facteurs humains - Définir tous les facteurs ergonomiques à prendre en compte dans la conception et l'adaptation de systèmes de communication embarqués en vue de s'assurer que ces systèmes contribuent à rehausser la sécurité routière, et non à la diminuer.

Etude de marché - Faire une enquête au téléphone et par la poste auprès d'associations susceptibles d'être intéressées par les systèmes de communication embarqués ainsi qu'auprès d'un certain nombre de leurs membres les plus importants, et faire des entrevues individuelles avec un petit nombre de personnes intéressées.

Enquête auprès des fournisseurs - Faire une enquête au téléphone et par la poste auprès d'actuels et d'éventuels fournisseurs canadiens de matériels et de logiciels aptes à équiper les systèmes envisagés.

Projet de diffusion d'information - Tenir les éventuels usagers et fournisseurs de systèmes de communication mobiles au courant de l'état d'avancement des technologies dans ce domaine et de leurs applications possibles, sans oublier les corps réglementaires compétents.

Projet d'élaboration d'une stratégie nationale - Elaborer une stratégie nationale pour faire avancer la recherche, la mise au point, la mise à l'essai expérimental, la fabrication et l'exploitation de systèmes de communication mobiles au Canada.

Les futurs systèmes de communication mobiles intégreront, outre la localisation du véhicule, la navigation et le guidage routier, de nombreuses autres fonctions qui seront d'une aide précieuse à la conduite. Toutefois, les intérêts canadiens ne doivent pas tarder à agir s'ils veulent exploiter une part de ce filon prometteur en participant pleinement à la conception, la mise au point et la fabrication de tels systèmes et à leur adaptation à diverses applications possibles.

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1. INTRODUCTION

1.1 MOBILE INFORMATION SYSTEMS

1.1.1 Background

New in-vehicle technologies are emerging which will have a significant, but as yet unexplored impact on road transportation in Canada - particularly within large urban centres, but also in the inter-city transportation sector. Within the 1990-2000 time frame, self-contained and other automobile navigation systems will become widely available, at reasonable cost to ordinary automobiles as well as to truck and bus fleets. These systems, most of which will use a map data base stored in an on-board micro-computer, will provide the capability for in-vehicle route guidance.

In response to the demand for two-way data communications for the so-called "mobile office" - a number of radio systems, including data cellular, will appear in the same time-frame to compete in this market. These technologies, in combination, present significant opportunities for dynamic route guidance, interactive traffic management and vehicle location monitoring which are bound to have far-reaching impacts in many person and goods transportation areas.

1.1.2 Definition of M.I.S.

Mobile information systems are usually considered to include all those in-vehicle systems that provide one or more of the following primary functions:

* positioning, self-contained navigation and inter-active route guidance (on-board or remote)
* vehicle/driver/cargo monitoring, control and collision avoidance
* data and text management: retrieval, display and manipulation
* mobile communications: receiving and transmitting of voice and data.

The focus during Phase I & II has been on those on-board devices which can display the vehicle's position (relative to a map base) in some form within the vehicle itself, and facilitate or perform on-board navigation and route guidance.

1.2 PROJECT PURPOSE

The objectives for the "Mobile Information Systems Impact Study" are to:

Phase I

* formulate a framework for describing mobile information and in-vehicle guidance systems: goals, objectives and classifications
* review the status of technologies currently commercially available or under active development
* outline human factors issues and requirements.

Phase II

* identify probable applications for each of the primary technologies
* speculate on market penetrations
* suggest roles for federal, provincial and municipal governments, vis-a-vis:
  - regulations & standards
  - research, development and demonstrations.

1.3 HISTORICAL BACKGROUND FOR MOBILE SYSTEMS

1.3.1 Context

Navigation is an applied science that uses a variety of techniques and procedures to determine present position, heading and/or direction and distance to a destination. For centuries, navigation (of ships at sea) centered on the use of celestial observations and compass readings to fix the position and set the course. Automobile navigation has traditionally been accomplished by reference to external road signs and landmarks while travelling over routes constrained (unlike sea, air and space navigation) to finite networks of streets and roads. Commonly used in-vehicle aids for automobile navigation have been essentially limited to road maps, the odometer, and an occasional magnetic compass. Except for a brief period of activity starting around 1910, automobile navigation had received little attention compared to sea, air and space navigation prior to the recent flurry of engineering projects, concept car showings and media reports.

1.3.2 Ancient Origins

Odometer is the only navigation aid universally installed in automobiles, and it appears as an element of virtually every high-technology navigation system. Hero of Alexandria and Vitruvius authored the first western descriptions of odometer approximately 2000 years ago (Ref 1), and it started appearing in the Chinese literature during the Later Han Dynasty (25-220 A.D.). Technology historians claim the odometer to be the earliest example of gear-train driven jack-work (Ref 2).

Modern odometers, with numeral-faced cylinders for indicating distance travelled in tenths, units, tens, hundreds, etc., look nothing like their early ancestors. One of Hero's models recorded distance by periodically dropping stones into recepticals. An ancient Chinese odometer known as the "drum carriage" operated two automatons. One figure struck a drum at the

end of every li (about 0.5 km) and the second figure rang a bell at the end of every ten li (Ref 2).

South Pointing Carriage is the earliest known example of a land vehicle navigation system. This direction-keeping device is a Chinese invention dating back to 200-300 A.D., possibly earlier. Chinese literature confused the south-pointing carriage with the magnetic compass (invented almost 1000 years later) so thoroughly that historical research has only recently established that the south-pointing carriage had nothing to do with magnetism (Ref 3). Instead, it was based on the principle (now called "the differential odometer") that for a given change in vehicle heading, a vehicle's outer wheels travel a mathematically-predictable distance farther than the inner wheels. When changing heading, a gear train driven by a south-pointing carriage's outer wheel automatically engaged and rotated a horizontal turntable to exactly offset the change in heading. Thus a figure with an outstretched arm mounted on the turntable always pointed in the original direction regardless of which way the carriage turned.

Colorful legends tell of south-pointing carriages guiding important emissaries across China's broad plains, and leading warriors through battlefield smoke screens. But there are questions about its practical accuracy. Indeed, tests of the differential odometer as the sole basis for a mechanical dead reckoning system indicated heading errors averaging approximately 20 degrees per mile of travel (Ref 4).

Magnetic Compass was described in the Chinese literature in the 11th century A.D., a century earlier than the first European mention (Ref 3). The earliest compasses were magnetized needles floated on a liquid surface and would not have been suited for use aboard land vehicles of the time. Indeed, cursory review of the literature reveals no close association with land vehicles prior to the automobile.

1.3.3 Early Mechanical Systems

The first wave of vehicular navigation devices appeared with the introduction of mass-produced automobiles early this cen-

tury. A cursory search of U.S. patent files reveals that dozens of devices for automobile route guidance were patented between 1910 and 1920. Several of these early devices were discussed in the annual "automobile" issue of Scientific American in 1911 (Ref 5):

> "All tourists by automobile know the difficulties and annoyances of finding and keeping on the best routes to their objective...It has been the object of a number of inventors...to overcome these difficulties and simplify the unwelcome task of finding the route by producing mechanical devices for attachment to the car that would serve to guide the motorist unerringly over any chosen route... Three such instruments have been perfected and put in the market."

Virtually all of the automatic route guides for automobiles that appeared early this century were mechanical devices driven by an odometer shaft. In fact, the odometer itself is a navigation device because it may be used in conjunction with road signs or maps to estimate present position. The automatic route guides, however, went a step further to provide specific instructions at decision points along the way - an approach that is now reappearing in some high-tech systems.

Jones Live-Map was one of the earliest, and apparently one of the most popular, mechanical route guides (Ref 5). It was invented in approximately 1909 by J. W. Jones who was also the inventor of the disk phonograph which bears certain resemblance to the Live-Map.

The Jones-Live Map consisted of a turntable driven slowly by a gear train connected by flexible shaft to one of the vehicle wheels. Paper disks for individual routes had a scale of miles printed around their perimeter, and were mounted on the turntable beneath a glass cover with a fixed pointer. Printed road directions keyed to specific distances from the beginning of a route came into view under the pointer at the time for execution. An advertisement for the Jones Live-Map claimed "You take all the puzzling corners and forks with never a pause. You never stop to inquire...."

A glance at the Jones Live-Map would show the driver how many miles had been travelled since starting a journey and how

many miles remained to be travelled, in addition to the exact location along the route. When making a side trip or detour from the charted route, it was necessary to reset the pointer (similar to setting a watch) to the proper place upon returning to the original route.

Chadwick Road Guide was introduced in 1910 by Lee Sherman Chadwick, an American engineer (Ref 6). Like the Live-Map, the Chadwick device revolved a calibrated disk in synchronization with distance travelled. However, the disk was of metal and contained punched holes spaced to coincide with decision points along the route represented by the disk.

An array of spring-loaded pins behind the slowly rotating disk were normally depressed, but when a punched hole came over a pin, the pin released and activated a signal arm which appeared behind the window bearing a color-coded symbol indicating the action to be taken. Simultaneously, a bell would sound to draw the driver's attention to the signal. Moreover, beneath a pointer the same disk gave printed information regarding the location or the action to be taken.

The Chadwick road guide was the most highly automated device of its type, and sold for $75 which is equivalent to roughly $1000 in today's U.S. dollars, thus approaching the price of the Etak Navigator™, a high-technology automobile navigation system now on the market in the United States.

Rhodes Route Indicator, an odometer-like device whose cylinders were printed with directional signals as well as numerals, was another early automated route guide and was patented by Rhodes in 1911 (Ref 7). Whereas the above devices required a specially printed paper disk or punched metal disk for each route, Rhodes' "Route Indicator" was programmable. Following a key given in a master route book, alternating cylinders printed with direction signals and numerals were initialized and positioned in such a way that the proper route instruction (eg: 'straight ahead, 4.9' 'right, 1.7' 'left, 3.5' etc.) would automatically appear under a sliding index as a bell sounded to alert the driver.

Other early devices included strip maps that advanced with distance travelled. An example is the route-indicator patent-

ed by Lindenthaler in 1909 in which directions and distances printed on a ribbon came in view as each turn was approached (Ref 8).

VEPOL, an experimental dead-reckoning system for determining and displaying vehicle heading and X,Y coordinates, was perhaps the last purely mechanical vehicular navigation device developed in the United States (Ref 4). VEPOL was based upon two odometers, one driven by a left wheel and one driven by a right wheel. A mechanical computer derived vehicle heading and resolved distance travelled into X,Y components based on the differential odometer principle, ie: during a turn the outer wheel of a vehicle of certain width will travel further than the inner wheel by an amount which is related to change in heading.

VEPOL's accuracy was insufficient for its intended application as the on-board component of an automated vehicle location system for use by police and other central dispatch offices. However, it did reintroduce the concept of the differential odometer which was originally used in the south pointing carriage.

1.3.4 Early Electronic Systems

The need for route guidance devices apparently diminished as the expanding roadway system became better marked with standardized signs, and as reliable road maps and guide books became available. With the advent of electrical servomechanisms, electronic controls and finally, the digital computer, mechanical approaches to automobile navigation and route guidance faded into the background. Two systems from the transitional period from World War II through the 1970s are described in the following.

Vehicular Odograph, developed for military vehicles during World War II by the U. S. Army Corps of Engineers, was one of the earliest land vehicle navigation systems to incorporate electronic elements (Ref 9). The major components of the vehicular odograph include a magnetic compass which was read by a light beam and photocell arrangement. The compass output drove a servomechanism to rotate a mechanical shaft

corresponding to vehicle heading. The compass shaft was coupled to a mechanical computer in the plotting unit which resolved travel distance from an odometer shaft into X,Y components, and drove a stylus to automatically plot the vehicle's course on a map of corresponding scale.

The vehicular odograph's compass was surrounded by permanent magnets and pieces of soft iron whose locations and orientations could be adjusted to offset magnetic field perturbations caused by the vehicle in which it was installed. The vehicular odograph, which exhibited a wide range of accuracy depending upon terrain, vehicle jolting, operator skills, etc., typically accumulated 1km of error for each 50-150km driven (Ref 10).

Land-Vehicle System - a 1965 publication describes a Canadian military land-vehicle system also providing continuous dead reckoning of position based on mileage and compass course (Ref 11). Mechanical inputs from an odometer cable and a compass-driven servomechanism were continuously resolved by a ball resolver into the rectangular components of distance travelled. The rotation of one output shaft corresponded to distance travelled east or west and that of a second output shaft corresponded to north or south. The output shafts connected to electrical pulsing systems which drove heading and position indicators and a plotter. An illuminated cursor shaped to show heading as well as position was projected on the underside of a map.

A historical summary of vehicle navigation developments is presented in Exhibit 1.

EXHIBIT 1

VEHICLE NAVIGATION DEVELOPMENTS

DATE	TECHNOLOGY
< 60 AD	Odometer
200 - 300	Differential Odometer
1100 - 1200	Magnetic Compass
1906	Gyrocompass
1910	Programmed Routes
1940	Loran Positioning
1964	Satellite Positioning
1966	Proximity Beacon
1971	Map Matching

2. STATE-OF-THE-ART REVIEW

The effectiveness of navigation technology is traditionally rated in terms of positioning accuracy. Effective automobile navigation requires that position be determined with sufficient accuracy to identify the street or road being travelled and to delineate among closely-spaced intersections. This generally means that vehicle position must be determined to within a small fraction of a block. A typical block is 200 metres (660 ft) long.

Improvements in accuracy achieved in recent decades with multipurpose radio-location technologies, as reported by Luse and Malla (Ref 12), are presented in Exhibit 2. Although not strictly comparable because their accuracies are expressed relative to digitized maps (rather than absolute location), the accuracies of map-matching systems reported by French & Lang (Ref 13) and by Honey & Zavoli (Ref 14) are included. It is also useful to note that, in ARCS, the digitized map data was captured by driving over the intended routes. While each of the values plotted in Exhibit 2 is subject to qualifications (eg: the Loran-C accuracy is from when it was first introduced in the 1960s; better accuracy can be obtained today), the trend clearly indicates that we are entering an era in which vehicle location can be pinpointed to individual streets and intersections.

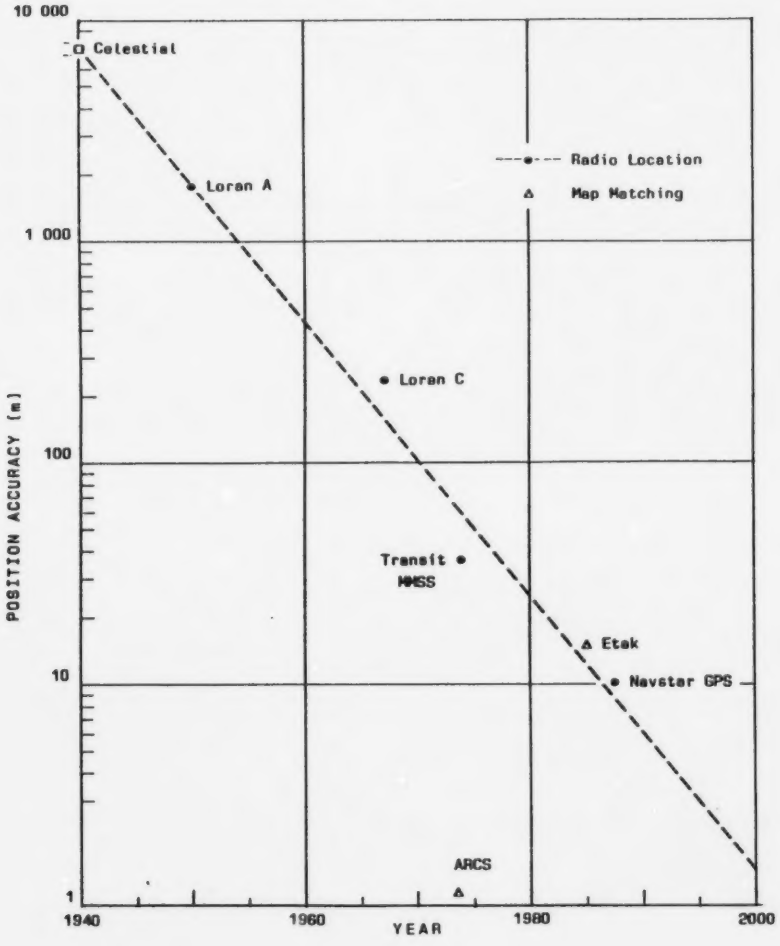
2.1 NAVIGATION TECHNIQUES

The wide range of systems approaches for automobile navigation which have appeared throughout the world during the 1980s defies precise categorization. However, it is convenient to use the classifications characterized in Exhibit 3 for discussing contemporary system concepts (Ref 15).

Several navigation systems for automobiles based solely upon dead-reckoning have been developed in other countries during recent years. However, in the United States dead-reckoning appears only as sub-systems in satellite-positioning and map-matching systems. Neither has any further work, except for

EXHIBIT 2

IMPROVEMENTS IN POSITION ACCURACY



Notes: Indicated accuracy does not necessarily relate to area covered in the same way for each navigation technique - ie. the signal losses (position failure) due to tall buildings, electrical transformers, thick foliage etc would be different for each of the systems.

ARCS: Digital mapping was assembled by driving over delivery routes in data acquisition mode, in order to obtain sufficient accuracy for specific addresses; further calibration runs over the entire route were used to refine the algorithms for the differential odometer. (ordinarily, as for Etak, network data is independently entered from mapping sources, and no pre-runs over any routes are undertaken).

Navstar GPS: The indicated accuracy assumes use of the (military only) P-code, or use of differential GPS (referencing to known base stations).

Source: Ref 14a

EXHIBIT 3
NAVIGATION TECHNIQUES

TECHNIQUE	TYPICAL CHARACTERISTICS
DEAD RECKONING	Low vehicular expense
	Autonomous operation
	Accuracy degrades with travel
	Requires manual position updates
PROXIMITY BEACON	Low to moderate vehicular expense
	Requires costly roadway equipment
	Dead reckoning (or visual tracking) between beacons
GROUND-BASED RADIO	
- Loran-C	Moderate vehicular expense (+possible signal charge)
	Requires more base stations (for national coverage)
	Signal sensitive to electromagnetic interference
- Cellular	Moderate/high vehicular exp. (transmission charge)
	Low accuracy without roadside transponder (or dead reckoning) backup
	Exceptional voice&data communications capabilities
SATELLITE	High vehicular expense (+ possible signal charge)
	Requires satellite service
	High accuracy when reception good
	Dead reckoning backup required
MAP MATCHING	Moderate vehicular expense
	Requires extensive map data base
	High accuracy when map correct and detailed
	Corrects vehicle's position on map
	Can only be used in conjunction with other techniques (eg. dead reckoning) to determine vehicle position relative to map.

limited design concept studies, been performed in the U.S. on proximity-beacon systems since the cancellation of the ERGS project in 1970.

Microprocessor-based improvements in Loran-C hyperbolic radio-positioning receivers and the scheduled completion of mid-continent coverage suggest the possibility of Loran-C subsystems for automobile navigation. However, for the moment, navigation system developments in the United States appear to be confined to satellite positioning and map-matching augmented dead-reckoning approaches.

2.1.1 Dead Reckoning

Dead reckoning is the process of determining a vehicle's location and heading relative to an initial position by integrating measured increments and directions of travel. The method and equations are presented, in an x-y coordinate system, in Exhibit 4.

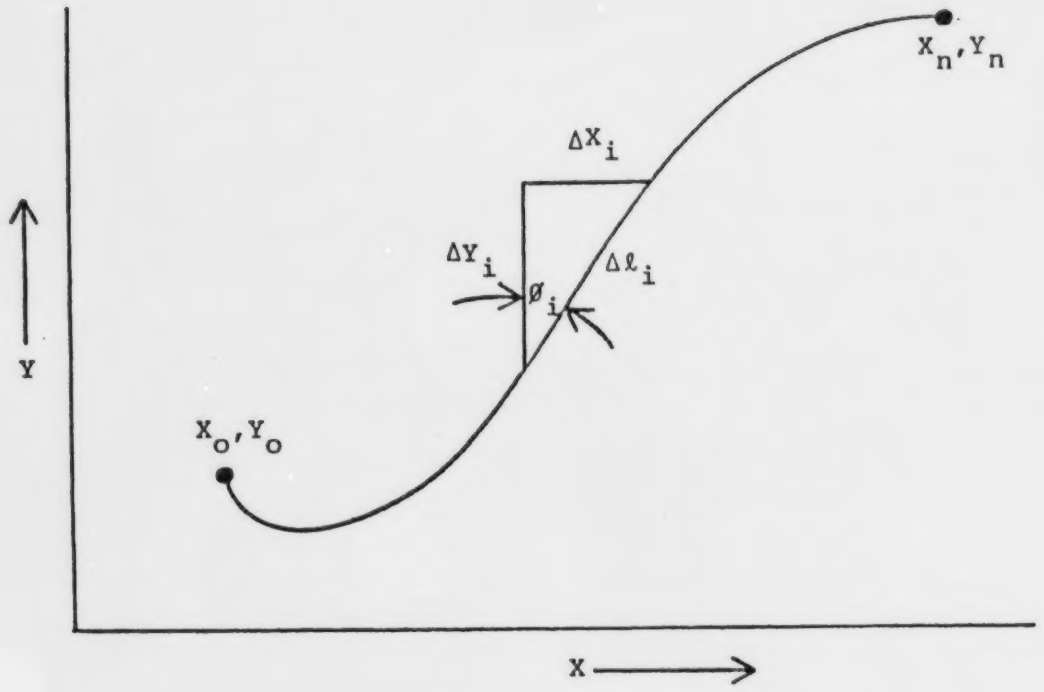
Most dead-reckoning technologies used in automobile navigation systems were developed long before the automobile itself. These include the odometer, the differential odometer, and the magnetic compass. The gyrocompass, developed in 1906, has seen only limited usage in automobile systems. Inertial systems are presently expensive and ill-suited for the harsh automotive environment.

Dead reckoning accuracy is difficult to quantify because it continuously decreases with time and/or distance. Even the most precise dead reckoning navigation systems require periodic reinitialization.

Odometer Conventional mechanical odometers for automobiles are usually driven by flexible shafts attached to the drive train, and display distances to the nearest 0.1 mile. Electronic odometers, which can measure travel increments smaller than one inch, are often used in automobile navigation systems. These provide sensor signals from a rotating shaft or wheel and apply a conversion factor to obtain distance travelled.

EXHIBIT 4

DEAD-RECKONING FORMULATION



$$X_n = X_o + \sum_i \Delta X_i$$

$$= X_o + \sum_i \Delta \ell_i \text{SIN} \phi_i$$

$$Y_n = Y_o + \sum_i \Delta Y_i$$

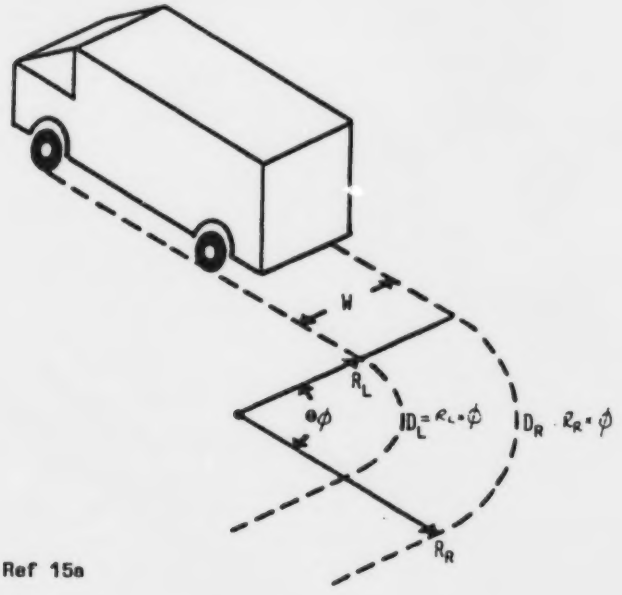
$$= Y_o + \sum_i \Delta \ell_i \text{COS} \phi_i$$

Differential Odometer A differential odometer is essentially a pair of odometers, one each for wheels paired on opposite sides of the vehicle. As illustrated in Exhibit 5, when the vehicle changes heading, outer wheels travel further than inner wheels by an amount (ΔD) that is equal to the product of the change in heading (Δ) and the vehicle's width (W):

$$\Delta D = W \times \Delta \qquad (3)$$

EXHIBIT 5

DIFFERENTIAL ODOMETER PARAMETERS



Source: Ref 15a

Thus, by measuring the differential travel of opposite wheels, a vehicle's path and heading relative to its starting point may be computed using algorithms based on Equation 3.

The differential odometer was tested as a basis for vehicle location monitoring by Meyer (Ref 4). He used the odometer and a mechanical dead-reckoning computer to keep track of vehicle coordinates and heading. Test results indicated heading errors averaging approximately 20 degrees per mile of travel. Couple of years later, French & Lang (Ref 13) developed and

tested an electronic version of the differential odometer in an automatic route guidance system which included a map-matching algorithm to maintain much higher accuracy.

Magnetic Compass The magnetic compass's well-known accuracy problems due to anomalies in the earth's magnetic field become more severe when installed in an automobile because of induced fields depending upon vehicle heading. In addition, an automobile may have a permanent magnetic field of its own, and sub-permanent magnetism may be acquired or lost when hitting bumps.

Nonetheless, magnetic compasses have long been used as heading indicators for automobiles, and modern versions of the compass are now frequently used as a component in integrated navigation systems for automobiles. Whereas the compass first appeared around the 11th century in the form of a magnetic needle floated on a liquid surface, current versions include compact solid state fluxgate compasses with software algorithms for compensating errors due to both permanent and induced magnetism of the vehicle.

Gyrocompass The gyrocompass, which was patented in Germany in 1906 by Auschutz-Kampfe, uses the gyroscopic inertia principle to maintain a constant reference alignment in space. One of the few examples of gyrocompass being incorporated in an automobile navigation system is the Lunar Roving Vehicle used on the moon where a magnetic compass would be useless. The LRV, driven on the moon's surface during Apollo Missions 15, 16 and 17, had a dead reckoning navigation system which continuously measured direction and distance travelled, and periodically calculated vehicle position. Using gyrocompass reference heading and magnetic odometer inputs, the system could return the astronauts to within about 90 metres of their origin after a 32 km journey (Ref 16).

2.1.2 Proximity Device

System Concept This approach uses strategically located short-range transmitters, and the very reception of their location-coded signals infers the receiving vehicle's instantaneous location. The widest application of proximity technolo-

gy is for automatic vehicle location (AVL) monitoring systems such as those used for monitoring the location and status of transit buses from a central dispatch office (Ref 17). An on-board system receives and stores a location code as the vehicle passes a proximity beacon or "electronic signpost". Upon periodic polling, the last device location and the distance or time since passing the device are automatically radioed to the dispatch computer.

System Variations Several variations of the proximity approach, some involving two-way communications with equipped vehicles, have been investigated for interactive route guidance (Ref 18). Typically, the driver enters a destination code on the vehicle panel for automatic transmission to a roadside unit as the vehicle approaches instrumented intersections. The roadside unit, which may operate autonomously, or be networked with a traffic management system, analyzes the destination code and instantly transmits route instructions to the vehicle. Alternatively, the roadside unit may only transmit its location to the vehicle where an on-board computer, using stored road network data, will generate instructions for continuing the route from the identified location.

DAIR (Driver Aided Information and Routing System) - proximity beacon navigation was researched in the United States starting with DAIR in mid-1960's. DAIR, which used roadbed arrays of magnets arranged in binary code to communicate location to passing vehicles, was the subject of limited development and testing by General Motors (Ref 19).

ERGS (Electronic Route Guidance System) is a proximity-device type vehicle navigation system that was researched by the U.S. Federal Highway Administration during the late 1960s as a means of controlling and distributing the flow of traffic (Ref 20).

With the ERGS concept, equipped vehicles were to interact via two-way communications with roadside units to obtain traffic-responsive routing instructions at decision points in the road network. An in-vehicle console with thumbwheel switches permits the driver to enter a selected destination code. The

code is transmitted when triggered by a roadside unit as approaching key intersections. The roadside unit immediately analyzes routing to the destination and transmits instructions for display on the vehicle's console. (For a system diagram, see Exhibit 6a.)

Although technically sound, ERGS required expensive roadside infrastructure, and the development effort was terminated by Congressional mandate in 1970 following limited testing of various equipment modules. However, similar approaches have been carried through further stages of develop-ment and testing and are still under active consideration in England, Japan and West Germany.

CACS (Comprehensive Automobile Traffic Control System) was the subject of studies and experiments pursued for six years starting in 1973, and provided the earliest demonstration of true route guidance equipment in Japan in the late 1970's. Similar to ERGS, CACS included in-car devices that communicate with roadside units, and a central computer to determine best routes for driver guidance. The CACS system was originally demonstrated in Tokyo, and has formed the basis for continued development of route guidance systems in Japan (Ref 21 & 22).

ALI , the first West German driver guidance and information system was, like CACS, a second generation proximity beacon system patterned after the first generation ERGS. Large-scale field testing began in mid-1979 (Ref 23) - and the results provided useful information for designing ALI-SCOUT, a third generation proximity systems (Ref 24).

ALI-SCOUT - a joint project of the West German Government, Siemens, Volkswagen, Blaupunkt and others - uses a combination of proximity beacon, dead-reckoning and map-matching techniques. ALI-SCOUT equipped vehicles receive approximately 8 KBytes of area road network and recommended route data each time a strategically located IR beacon is passed. Simplified graphic driving directions to the input destination are presented in real time on a dashboard LCD. Destination input and other system controls are via hand-held wireless remote-control unit. Vehicle driving times between beacons are trans-

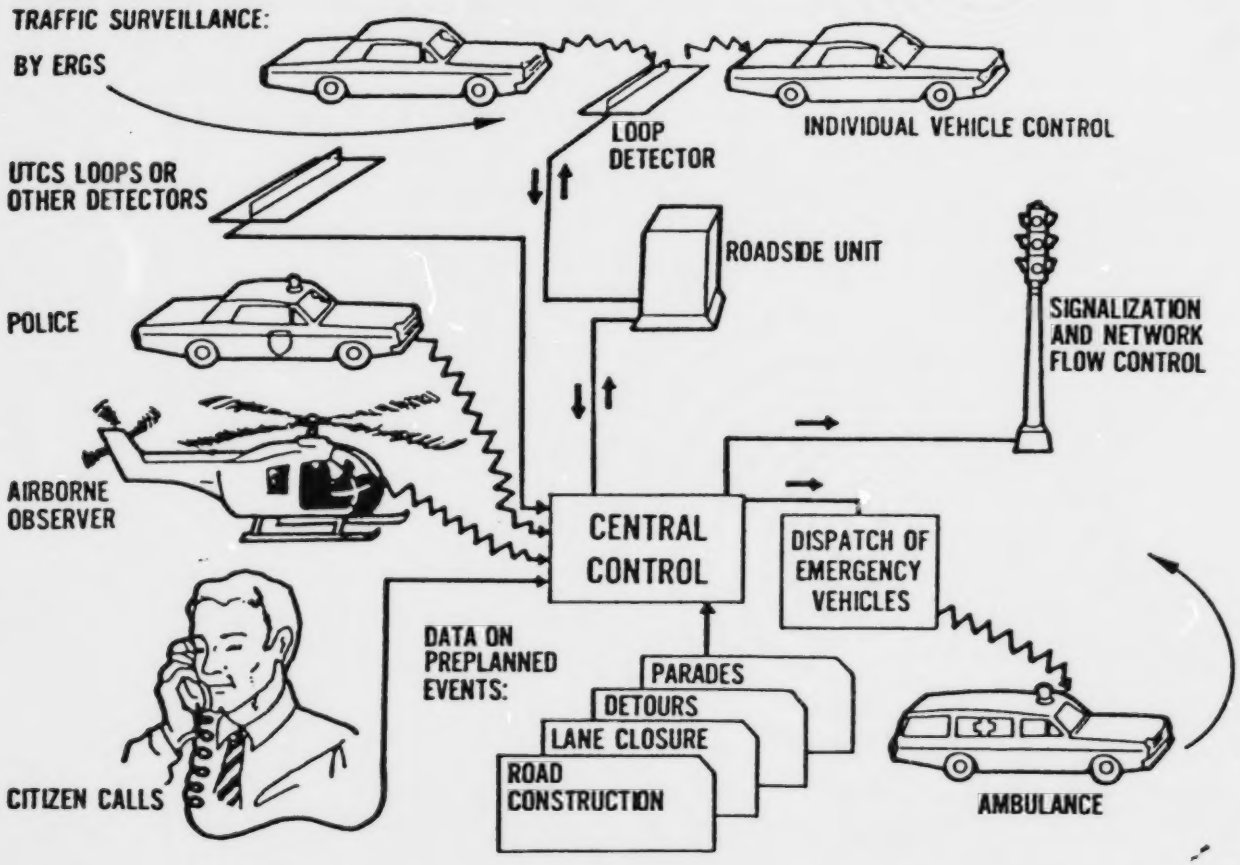
mitted to the beacons to aid in collecting traffic flow data. ALI-SCOUT will be subject to large-scale user tests in West Berlin starting in 1988. (For a system diagram, see Exhibit 6b.)

Autoguide , designed by the Transport and Road Research Laboratory of the UK Department of Transport (Ref 25), was initially similar in concept to the earlier U.S. ERGS, Japanese CACS and West German ALI systems. Approximately 700 London junctions (out to and including M25) would be outfitted with roadside beacons for two-way guidance communications with equipped vehicles. Most of the system's intelligence was to be built into the beacons; based on current and anticipated (en-route) traffic conditions, control centre computer recalculates routes and sends an updated 'look-up list' to each beacon. (For a system diagram, see Exhibit 6c.)

Autoguide, which is being demonstrated in London, has undergone extensive design changes and now uses two-way IR communication like ALI-SCOUT rather than inductive loops as originally planned. A proposed pilot system for London will be virtually identical to ALI-SCOUT except for minor differences in operating philosophy (Ref 25a).

EXHIBIT 6a

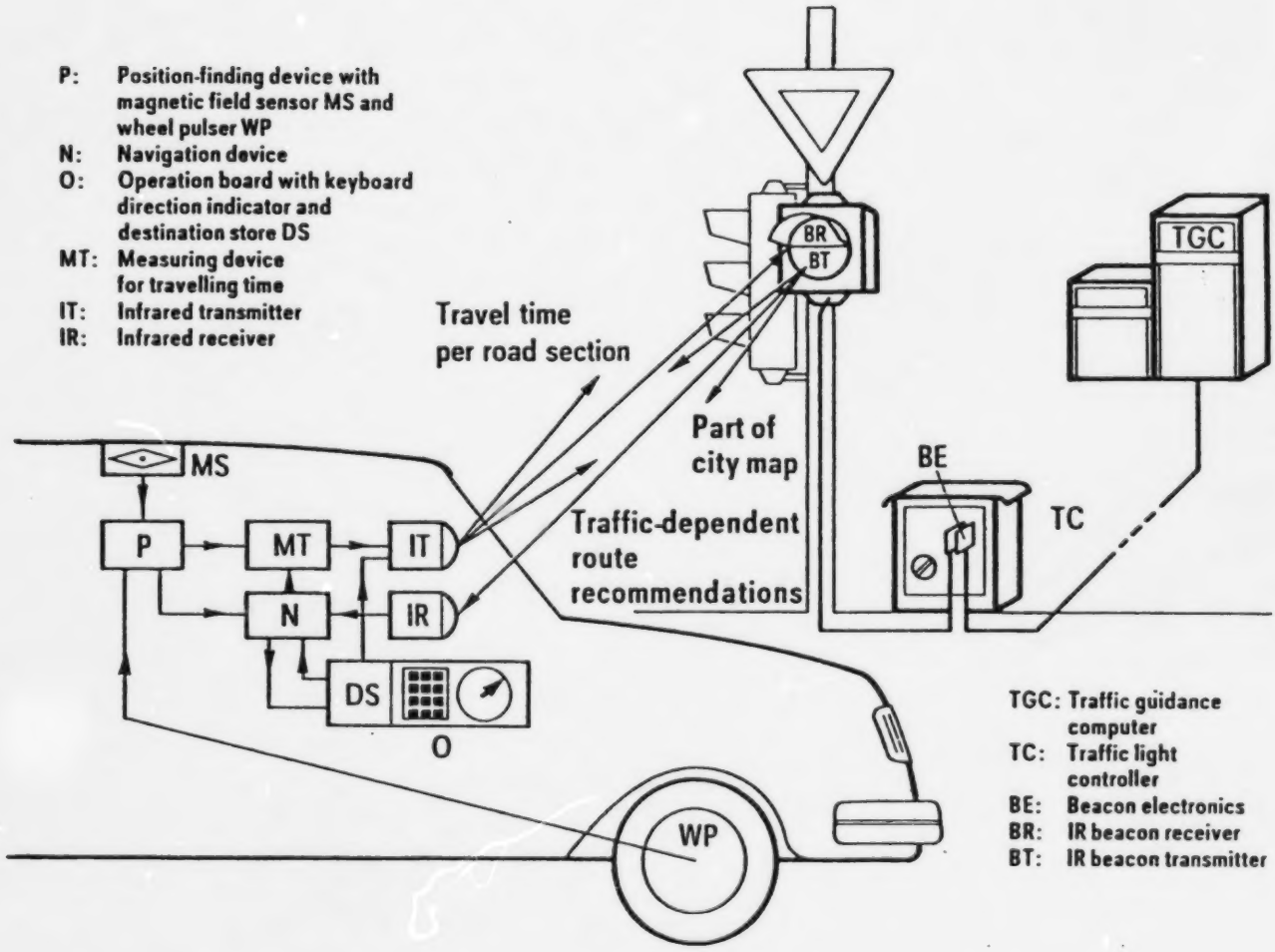
ERGS DYNAMIC ROUTE GUIDANCE SYSTEM CONCEPT



Source: Ref 20

EXHIBIT 6b

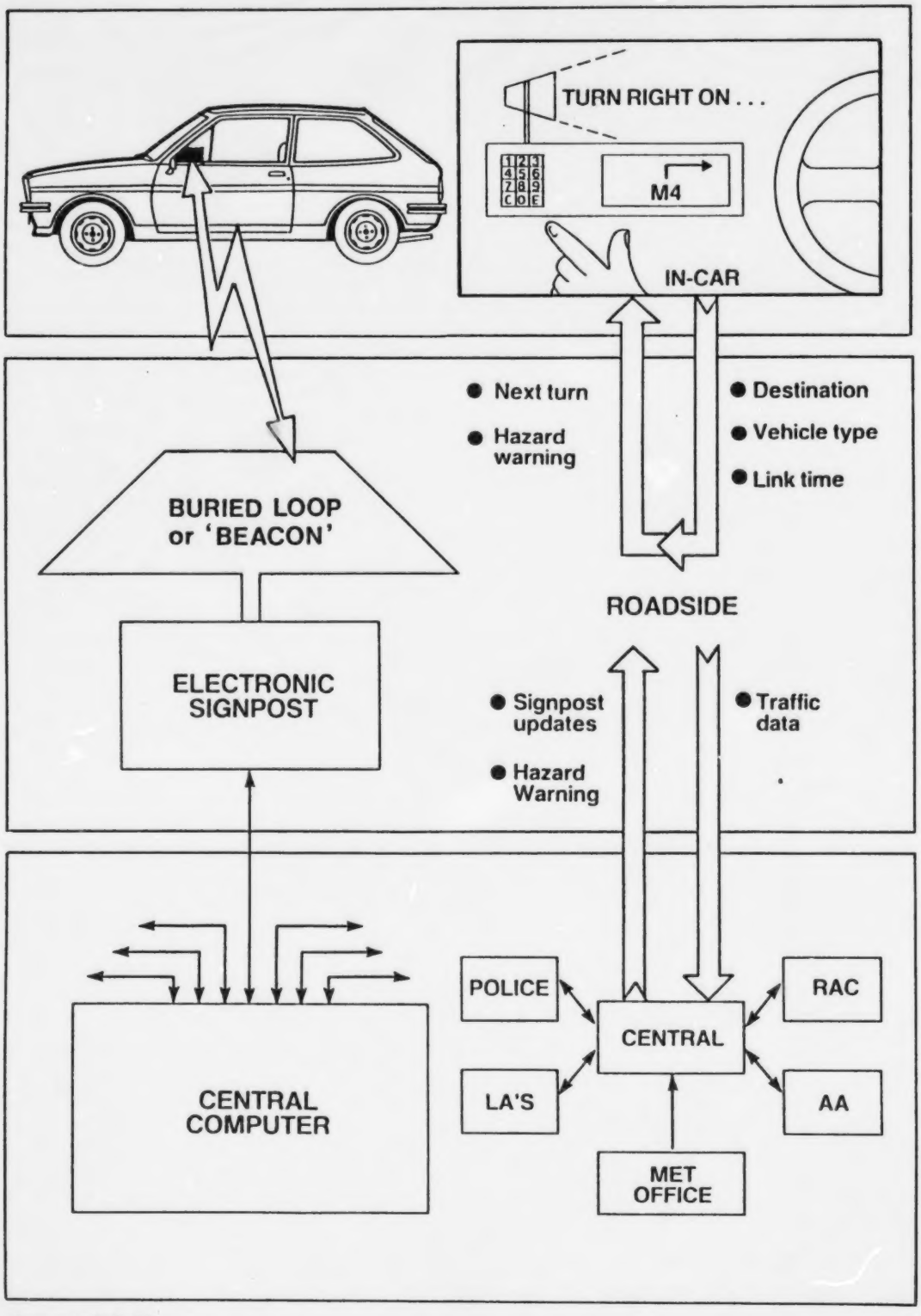
ALI-SCOUT OPERATING PRINCIPLE



Source: Ref 24

EXHIBIT 6c

AUTOGUIDE SYSTEM ELEMENTS



Source: Ref 25

2.1.3 Ground-Based Radio

Numerous navigation schemes, such as triangulation, phase trilateration, and pulse trilateration involve the use of ground-based radio signals in determining position. Of these, Loran has received the most attention as the basis for vehicle location and navigation systems.

Loran LOng RAnge Navigation, invented in 1940 by Loomis, is a hyperbolic navigation system using multiple pairs of ground-based master-slave transmitters. U.S. coverage is complete along all coasts and most inland areas except for a band from Texas to North Dakota (Ref 26). Additional transmitter chains are now being installed to cover the existing mid-continental gap. Loran-C coverage is extended through Canada by the Canadian West Coast Chain (GRI 5990) and the Canadian East Coast Chain (GRI 5930).

The master transmitter of a Loran-C chain emits a sequence of electromagnetic pulses which are received by a widely separated slave station and retransmitted on a slightly different frequency. The Loran user's receiver picks up both signals and analyses the difference in arrival time to establish a hyperbolic line-of-position associated with the time delay. Repetition of the procedure for a different master-slave pair yields the longitude and latitude of the receiver at the intersection of two hyperbolas.

The availability of microprocessor-controlled receivers with improved performance at lower cost makes Loran-C an attractive alternative to proximity device AVL in some cases. Motorola (Ref 26), II-Morrow (Ref 27) and Jaycor (Ref 28) have introduced Loran-C AVL systems.

But Loran has not been pursued extensively as the basis for automobile navigation systems, perhaps due to the incomplete geographic coverage as well as location inaccuracies typically as much as 200m. The only known use of Loran-based navigation in a U.S. automobile is a General Motors test system which also includes GPS positioning (Ref 29). Loran is also used in a Nissan delivery vehicle navigation system being

tested in Japan. It is gaining some acceptance as a means of tracking land vehicle location from central locations.

Other There is potential for new radio-trilateration approaches using subcarrier signals from cellular radio transmitters. One recent report indicated that the feasibility of such approaches might be known in 1988 (Ref 30).

2.1.4 Satellite Positioning

NAVSTAR GPS The Navstar Global Positioning System of the U.S. Department of Defense - which is still in the implementation stage, as most of the 18 satellites are yet to be launched into 12-hour orbits - has been considered as a basis for automobile navigation by all of the major U.S. motor companies (Ref 29, 31 and 32). When this satellite constellation is complete, any point on earth will always be within range of at least four Navstar satellites. According to a recent U.S. Air Force plan, the number of satellites will be increased to 24 (with a completion date of 1995). However, there is no commitment yet to funding this expanded program.

A GPS receiver could determine its three position coordinates by analyzing the travel time of signals from only three satellites if the receiver's clock was precisely synchronized with the atomic clocks that time the satellite signals. Given the timed signals from four satellites, the GPS receiver solves a system of four equations for its three position coordinates (P_x, P_y, P_z), and for the bias (C_B) of its less precise quartz clock:

$$(x_1-P_x)_2 + (y_1-P_y)_2 + (z_1-P_z)_2 = (R_1-C_B)_2 \quad (4)$$

$$(x_2-P_x)_2 + (y_2-P_y)_2 + (z_2-P_z)_2 = (R_2-C_B)_2 \quad (5)$$

$$(x_3-P_x)_2 + (y_3-P_y)_2 + (z_3-P_z)_2 = (R_3-C_B)_2 \quad (6)$$

$$(x_4-P_x)_2 + (y_4-P_y)_2 + (z_4-P_z)_2 = (R_4-C_B)_2 \quad (7)$$

where x_n, y_n, z_n, are position coordinates of the nth satellite based on ephemeris carried by its signal, and R_n is the range to the nth satellite.

Locations may thus be determined to within approximately 10 metres using Navstar GPS P-Code signals intended for authorized applications. Less precise C/A-Code signals for general use will permit location determination to within approximately 100 metres. By using established ground receiver/transmitter stations (whose locations are known precisely) to obtain a local correction signal - method known as differential GPS - vehicle units can obtain accuracies comparable to P-code.

Since 1983, General Motors Corporation has tested and demonstrated three navigation systems installed in a 1983 Buick Park Avenue (Ref 29): Navstar GPS, LORAN-C, and a flux-gate compass combined with an odometer sensor for dead reckoning. This test configuration permits the relative evaluation of three independent or integrated approaches.

The few satellites currently deployed limit the GPS navigation window to approximately 4 hours per day. LORAN-C is used at other times to demonstrate radio location along with the integrated map display. Both GPS and LORAN-C automatically shift to dead reckoning when their reference signals are obscured or when an unreasonable vehicle location is computed by GPS or LORAN-C. While there is no projected date for any of these systems to be introduced as a production option, GM will continue the development towards practical and affordable navigational aids (Ref 29).

Navstar GPS is also the basis for CLASS (Chrysler Laser Atlas and Satellite System) a concept displayed at the 1984 World's Fair in New Orleans (Ref 32). CLASS included a nationwide set of maps stored in image form on a video disc, and software for automatically selecting and displaying on a color CRT the map area incorporating the vehicle's current location as indicated by a cursor.

Nissan Motor Company Ltd and Mitsubishi Electric Company have also considered GPS as a basis for their automotive navigation systems. The Nissan system (Ref 33) includes a dead reckoning back-up, a vector-encoded map stored on CD-ROM, and a CRT display with route guidance. The Mitsubishi system (Ref 34), which also includes dead reckoning back-up and CD-ROM map storage, displays the vehicle's position on a colour CRT.

Although GPS has good potential accuracy and will provide continuous coverage, auxiliary dead reckoning is required in automobile applications to compensate for signal loss due to shadowing by buildings, bridges, foliage, etc. A recent evaluation of GPS for land vehicles notes that, because of differing ellipsoidal reference systems, the task of melding GPS location with local maps is formidable (Ref 35). Hence map-matching technologies, described below, may be useful with GPS as well as with dead reckoning.

TRANSIT Transit satellite navigation system, implemented by the U.S. Navy, has been operational since 1964 (Ref 36). Several Transit satellites in polar orbits at a height of approximately 1075 km are longitudinally-spaced to give worldwide, albeit intermittent, coverage. Each satellite transmits information which, in combination with measured Doppler characteristics, permits calculation of receiver location by iterative solution of a set of equations. Since a Transit satellite is not always in range, vehicle systems based on Transit must include dead reckoning for continuous determination of position between satellite passes.

Ford Motor Company demonstrated the integration of Transit satellite navigation with dead reckoning for automobiles with an operational system installed in a concept car in 1983 (Ref 31). This system, which was a major feature of a "Tripmonitor" cathode-ray tube information centre, periodically obtained accurate position from the Transit navigation satellites to update the primary location from the dead reckoning subsystem. The dead reckoning algorithm was based on vehicle speed and flux-gate magnetic compass information with software compensation for magnetic field pertubation by the vehicle.

The Ford Tripmonitor display is a touch-screen color CRT monitor permitting the grouping of various automotive displays into a single display. Several alternative screens available for the navigation feature included vehicle heading in N/S/E/W format, compass pointer display, digital heading in degrees, information on recent and next predicted satellite pass characteristics, and the vehicle's position in latitude and

longitude, in addition to map display with tracking of the vehicle's position.

GEOSTAR (Ref 37) and other commercial satellite systems, such as MOBILSAT (Ref 38), may offer future vehicular position information as well as two-way mobile communications services. With GEOSTAR, computers in a central facility calculate the users' position based on the measurement of round-trip signal transit times between the facility and the user transceivers, the signal returning through two geosynchronous satellites. The GEOSTAR System achieves high accuracy through the use of spread spectrum timing signals.

The GEOSTAR Satellite System is a licensed operator under the new Radio Determination Satellite Service (RDSS) that was approved by the U.S. Federal Communications Commission (FCC) in September of 1985. Once its two satellites are operational, it will be the world's first commercial network that provides radio-determination, radio-location, radio-navigation, two-way digital communications, and emergency assistance from the same set of user equipment.

GLONASS (Global Orbiting Navigation Satellite System), developed by the Soviet Union, is also in a pre-operational stage. Obvious parallels exist between GLONASS and the NAVSTAR Global Positioning System (GPS) under development in the United States.

A common periodicity exists amounting to 16 NAVSTAR orbits or 17 GLONASS orbits, equivalent to 8 whole days less 32.56 minutes. Two of three 120-degree orbital planes are occupied in the present pre-operational phase, one plane common to both systems.

Although GLONASS carries a C/A code at L1 and a P code at L1 and L2, as NAVSTAR does, certain of the GLOSNASS spacecraft have novel additional features in the form of spectral lines at the P code nulls and, in some cases, a carrier at the L2 centre frequency. The code length and code rate are approximately half those of NAVSTAR, indicating an inferior jamming margin and half the pseudo-range resolution (Ref 39).

2.1.5 Map Matching

Because the automobile is essentially constrained to a finite network of streets and roads, it is possible to match a vehicle's dead-reckoned course with a mathematically mapped route.

Graph theory is used as the conceptual framework for mathematically modelling maps of roads and streets as internodal vectors. Each vector represents the distance and direction of the road between two nodes defined by their coordinates. Thus, a particular route from a given initial location is a unique combination of vectors defined by the sequence of nodes along the route.

The pattern of the vehicle's path is analyzed as a sequence of vectors deduced from any of a variety of dead-reckoning processes. As the vehicle travels, its measured vector sequence is continuously compared with the mapped vector sequence. Each time a turn is executed whose sense, magnitude and location approximate those of a near-by mapped turn, the vehicle is presumed to be at the mapped location. The matching process thus removes any dead-reckoning error accumulated since the last turn.

Of course, problems can still rise from any deviation from the coded vector system (eg. into a multi-level, multi-exit garage, onto a parking lot with many exit points, etc), or from very closely-spaced intersections, or from electrical interferences affecting a dead reckoning compass (eg. particularly if near many-spoked round-abouts). In each case, a manual correction to position the system onto the correct vector of the map data base may have to be performed.

ARCS (Automatic Route Control System) allowed a particular route to be "programmed" as a unique sequence of mathematical vectors. An on-board computer was used to analyze dead-reckoning inputs and match the deduced vehicle path with programmed routes to automatically remove position discrepancies that would otherwise accumulate. The Automatic Route Control System (ARCS), demonstrated by French and Lang (Ref 13), was the first such map-matching route system.

ARCS used a differential odometer for dead reckoning and a map-matching algorithm to correlate each sequentially measured route vector with its map data base counterpart. The vehicle's location along the route was confirmed, and prerecorded audio route guidance instructions were issued where appropriate. A second version issued visual route instructions on a plasma display panel (Ref 40). Now called "Routeware™", this patented technology yielded an average location accuracy of 1.15 metres during extensive testing over newspaper delivery routes which were originally "mapped" by driving an ARCS-equipped vehicle over them while operating in a data acquisition mode.

Etak Navigator™ is a map-matching automobile navigation system for helping drivers efficiently find their way to destinations (Ref 14). The hardware includes a compass, dual wheel sensors (differential odometer), a cassette transport, a vector-type CRT display and a micro-processor. The compass is a two-axis flux-gate magnetometer which is digitally compensated during initial calibration. Wheel sensors are comprised of strips of rubberized magnetic tape adhered to the inside of two wheels with small ferrous-cored coils attached to the car in such a way that they remain stationary with respect to the wheel's axis of rotation.

The CRT displays a road map for the area surrounding the car. A symbol is fixed below the centre of the screen to indicate the location of the vehicle. As the vehicle moves, the map shifts and rotates under the symbol to maintain accurate position and orientation so that the driver may assimilate navigation information at a glance. The operator selects different map scales ranging from a detailed view of the nearby residential streets to a region-wide overview of the freeway system. Roads are categorized in several classes, and only streets of appropriate priority are displayed consistent with the map scale selected. A dynamic labeling algorithm labels streets most likely to be of interest to the operator. As the vehicle changes direction and the map rotates, the street labels are reoriented for easy reading.

The Etak system navigates by a combination of dead reckoning and map matching. The measurements from wheel and compass

sensors are combined to determine a sequence of positions which in turn is compared to a local map data base stored on a 3.5-MByte tape cassette. When the map-matching algorithm determines with high confidence a more likely current position for the vehicle, its position is adjusted and accumulated errors are thus eliminated. Map matching also enables the system to continuously refine sensor calibration for improved dead-reckoning accuracy.

A desired destination may be specified as the intersection of two streets or by street name and number. The selected destination shows on the map display as a flashing star.

In 1985 GM and Etak Inc, announced a licensing agreement giving GM exclusive rights to use Etak's navigation technology in original equipment for cars and trucks sold in North America. The Delco Electronics Division of GM is developing a system which will be functionally similar to the Etak Navigator and which will use the Etak map data base. The principal difference is that the map data base will be stored on CD-ROM rather than on tape cassettes. Maps will be displayed on a multi-function raster-scan color CRT rather than on a monochromatic vector-type CRT as in the original Etak system. Differential odometer signals will be adapted from wheel sensors used for anti-lock braking.

Bosch-Blaupunkt announced a licensing agreement with Etak in late 1987, giving them exclusive marketing rights in western Europe. The Bosch-Blaupunkt version called "Travelpilot" will also use CD-ROM for map storage and is scheduled for introduction in 1988.

Philips CARIN , a map-matching system developed for testing and demonstration by Philips, features the compact disc (CD-ROM) for storage of map data bases (Ref 41). This system includes a route-search algorithm and provides step-by-step route guidance. In the first version, a color CRT map display shows vehicle location relative to the surroundings, and voice instructions prompt the driver when operating in the route guidance mode. A more recent version, designed for possible production, uses a simplified LCD for route instruction and

does not include a CRT map display (Ref 42). An RDS communication link for receiving traffic data is also featured.

Bosch-Blaupunkt EVA map-matching system uses a differential odometer and includes route-search software to generate explicit route-guidance instructions (Ref 43). Turns at intersections, lane changes, etc are specified on an LCD in the form of simplified diagrams which show lane boundaries and use arrows to indicate the path to be taken. Voice capability is included, and is used to confirm destination entries. A CD-ROM version is under development.

Japanese Systems , recently under development by several manufacturers, illustrate the emerging popularity of map-matching augmented dead reckoning. The systems of Nippondenso (Ref 44), Sumitomo (Ref 45), Nissan (Ref 46) and Yazaki (Ref 47) include CRT displays and a variety of map data storage media and dead reckoning sub-systems. Some include radio navigation or proximity beacon receivers as well.

2.2 MOBILE COMMUNICATIONS TECHNIQUES

The principal systems identified for electronic transmission of information to and from vehicles are summarized in Exhibit 7. The more relevant systems are discussed individually following a brief review of mobile data communications considerations that are common to most approaches.

2.2.1 Data Communications

Radio has been used for years by the petroleum industry, gas and electric utilities, and other organizations that needed to transmit data from remote points to a central location - especially in areas where no phone lines existed or where the cost of those lines was prohibitive (considering the nature of the data being sent). The state-of-the-art in these applications for many years was to connect telephone-type modems to land mobile radio. This simple combination worked well provided that the data transmission needs were modest and the system was designed to cope with the harsh radio environment.

Momentary fading, noise, distortion or interference, which is only a minor annoyance during voice communications, will either alter or destroy a data stream. The net result was that transmissions were limited to 300 bits/second and retransmission was used to control errors.

From these beginnings, mobile data communications has evolved to include packet-radio systems, a new technology for transmission of data by radio networks interfaced to data devices and computers. Packet-radio systems are a derivative of methods pioneered on long-distance wired networks used by common carriers for both domestic and international data communications.

Over the past five years there has been extensive research and development in the creation of a new generation of packet-radio technology. It has resulted in a new resource to provide high accuracy, high throughput, and a wide range of networking possibilities for "bursty" thin-route point-to-multipoint data transmission by radio. Among the range of

EXHIBIT 7

MOBILE COMMUNICATIONS CHARACTERISTICS

SYSTEM	ELECTROMAGNETIC SPECTRUM	CHARACTERISTICS / COMMENTS
PROXIMITY BEACON	UHF (300MHz-3GHz)	One-way or two-way / data only
	Infrared (>3000GHz)	Local information Includes ALI-SCOUT and Autoguide
	Microwave(> 960MHz)	Requires special receiver
INDUCTIVE LOOP	30 kHz (typical)	One-way or two-way / data only Local information Requires special receiver
AM/FM BROADCAST	535-1605 kHz (AM)	107 channels - 10 kHz spacing
	88- 108 MHz (FM)	100 channels - 200 kHz spacing (1 One-way / voice only Area-wide information & accessible by all car radios Includes HAR (highway advisory radio)
BROADCAST SCA	88- 108 MHz & 53- 99 kHz sub-carrier	One-way / voice and data Area-wide information (subsidiary carrier authority) Requires decoding features at receiver ARI (automatic radio info) & RDS (radio data system)
NWR BROADCAST	162.400, 162.425, 162.450, 162.475, 162.500, 162.525 and 162.550 MHz	One-way / voice only National weather radio (area specific) Requires special receiver
LAND MOBILE RADIO	29.7 - 50 MHz	Two-way / voice&data (20kHz channel spacing) (2
	138 - 144 MHz	Heavy use in 130km wide border corrdr (30kHz spcn)
	148 - 149.9MHz	Signifcnt occupancy by provincial gvt radio systems
	150.05- 174 MHz	Severely congested by public & private licensees (3
	406.1 - 420 MHz	Paired duplex assignments; prov&munic systems
	420 - 430 MHz	Interference from US radioloc emergency operations
	430 - 450 MHz	Radiolocation activity geographically dispersed
	450 - 470 MHz	Includes 165000 land mobile assignments in Canada
	806 - 890 MHz	Includes compatible cellular & trunked operations (4
CELLULAR RADIO	825 - 845 MHz	One-way or two-way / voice and data
	870 - 890 MHz	Reqs dedicated traffic channel once lots of traffic Local and area-wide information Supports cellular telephone
SATELLITE MSS	1544 -1559 MHz dwn	One-way or two-way / voice and data
	1645.5-1660 MHz up	Area-wide information (commercl mobile sat service) Rural & urban reception; requires special receiver Signal only available a few hours

Notes:

1) A U.S. proposal calls for a new FM band 225-230 MHz. However with present technology, each 200kHz assignment results in non-use of 1600 kHz. This use-to-waste factor should be first improved. [VHF TV broadcasting: 54-72 & 76-88 & 174-216 MHz]

2) Includes radio paging, automatic repeaters, 12 mobile GLMRS channels, emergency traffic control, remote control & fire alarm systems, stn-to-stn linking, cordless telephones

3) Includes Maritime Mobile (distress and calling) 156.7625-156.8375. Assignments 172-174 MHz somewhat inhibited by TV channel 7.

4) Also: 890-902 (mobile reserve) & 928-929 + 952-953 (multipoint) & 929-932 (paging) MHz

possibilities today are radio transmission links at speeds of 2400 to 9600 bits/second, bit error rates of one uncorrected or one undetected wrong bit in 10^{11} bits transmitted, with throughput efficiencies of greater than 75 % using standard narrow land-mobile channels (Ref 48).

In the U.S., until recently, the Federal Communications Commission (FCC) rules limited non-voice transmission by land mobile radio to a maximum of two seconds without a break in the signal, and also required that such signals be secondary to voice transmission. Report and Order on Docket No. 82-470, released January 1983, revised the Land Mobile Rules eliminating the 2-second restriction and making digital data co-equal with voice. Nonetheless, shared voice and data communication is still a useful concept in land-mobile communications, and it is an important factor in the overall design and operation of dual mode systems.

In Canada, no such 2-second rule has existed. In dispatch bands particularly, efficiency is considered important - ie. a burst of digital data, containing for example a pick-up request for a courier, which can then be displayed on a screen in the vehicle, is clearly favoured in place of voice.

To minimize the occurrence of users hearing the data audio, CTCS (continuous tone coded squelch system) is often employed. A subaudible tone is transmitted only when the outbound (base to mobile) transmission is voice in nature. Outbound data transmissions are sent without the CTCS tone, thereby keeping all mobile speakers mute. A means of preventing data audio from being generated at the dispatch centre is also required. One method is to incorporate the function into the data communications controller (DCC). The DCC is a device which encodes and decodes data messages on the radio channel, then converts them for transmission over land line to the data processing device.

2.2.2 Broadcast SCA

In both Canada and the U.S., the transmission of ancillary information on 53-99 kHz subchannels with a band width of ± 5

kHz by commercial FM broadcast stations is allowed by so called 'subsidiary carrier authority'(SCA). Reception of these subchannels by car radios requires a special feature to detect and decode SCA messages. A current example is the ARI (Automatic Road Information) system for local area traffic advisories by voice transmission (Ref 49).

Use of this approach for area broadcast of digitized information on current traffic distributions, map data updates, etc, to the motoring public would require relatively little addition to the infrastructure, but would have to compete with other uses for SCA channels, such as paging services, background music, stock quotation services, etc. In-vehicle equipment (aside from the navigation system that would use the received data) would also be minimal, and would consist of an attachment to, or a special version of, the FM radio receiver that is already commonplace in automobiles.

2.2.3 Proximity Devices

There are three basic types of proximity device in use or under test today:

* inductive loops buried in the roadway
* low powered radio transmitters at the roadside, variously labelled as proximity beacons or electronic signposts
* high-capacity infrared communication beacons attached to traffic signal lights or road signs.

Accordingly, there also several different types of on-board receivers. While their cost is hard to estimate, they are generally far less expensive than radio location receivers.

The use of beacons to provide automatic vehicle location for urban transit systems is on the increase (eg. by TTC in Toronto). Two major demonstrations of navigation equipment in Europe - which will provide extensive communication functions as well as position updating - will be based on the use of infrared beacons (Section 2.1.2). In the U.S., proximity devices seem to have given way to autonomous on-board technologies in the planning of vehicle navigation systems. The formidable number of beacon locations, that would have to be

outfitted and connected by communications links to control centres, is considered to present a major cost obstacle.

The above arguments against and in favour of proximity beacons also apply to inductive loops as a means of road-vehicle communications. Inductive loops have the added disadvantage of requiring traffic disruption for installation. They also offer relatively low data communication rates.

2.2.4 Land Mobile Radio

Widespread use of land mobile radio for two-way voice communication for fleet management has been severely limited by the amount of spectrum allocated for this purpose. New technologies such as trunking and digital addressing gain more traffic capability within the available frequencies. However, the greatest potential gains in land mobile utilization will result from increased use of data communications as an alternative to voice communications. Also, the voice communications required of two-way land mobile radio for many applications may be handled adequately and less expensively by cellular radio telephone.

2.2.6 Cellular Radio

Cellular radio telephones have provided a major step forward for both business and personal voice communications in the automotive environment. The potential for cellular telephone data communication is expected to broaden the cellular applications during the next several years. However, the present scheme of using cellular technology exclusively for full-duplex individually addressed communications will limit the potential use of cellular radio in conjunction with navigation and route guidance systems.

Effective adaptation of cellular radio technology to the data communications requirements of navigation and route guidance might require the establishment of a dedicated channel for repeatedly broadcasting the same map update data, traffic data, etc., by all cell transmitters in the local area served by a cellular system. Equipped vehicles would have special

receive-only units to detect the data for transfer to the on-board system.

The types and prices of land mobile radios or cellular radio telephones are not necessarily different because they are used with an on-board navigation or route guidance system. However, a modem is generally required to interface the communications devices with the navigation computer. Standard commercially available modems are typically used for land mobile radio; specially designed "smart" modems are now becoming available for data communications via cellular telephone.

Another transmitter, such as an automatic vehicle identification (AVI) electronic license plate transponder, may simply send out the vehicle I.D. to roadside interrogators for traffic counting (eg. by vehicle type and by home base), for demand management (eg. road user charges, area access control) and for law enforcement purposes.

2.2.7 Satellite

The U.S. Federal Communications Commission has started the regulatory process that will lead to commercial mobile satellite service (MSS) and, on 24 July 1986, announced a spectral allocation of 27 MHz in the L-band (~1500 MHz) for this purpose. Twelve contenders have applied for license to operate the mobile satellite service. Lately there has been however a scramble for financial backers due to the requirement of having to place $5 Million in an escrow account.

Representative of the proposed services are those promulgated by the Mobile Satellite Corporation MOBILSAT^{SM} (Ref 38):

1) Voice Communications
   a) Interconnected mobile radio telephone
   b) One-way and two-way radio dispatch
   c) Rural residential telephone
   d) Pay-telephone-type radio telephone service for passengers (including airline, rail and ship passengers)
   e) One-way tone-and-voice paging and dispatch.

2) Data Communications

   a) 1-way & 2-way radio paging and alphanumeric messaging
   b) Vehicle location and tracking
   c) Vehicle operational data
   d) Remote monitoring and control
   e) Narrowband (low speed) data transmission
   f) Wideband data transmission.

The potential use of MSS for one-way data communications in support of vehicular navigation and traffic management faces obstacles which may be resolved in time. Allocation of L-Band rather than UHF spectrum will require more costly receivers (or perhaps larger antennas) because of low signal strength due to higher atmospheric attenuation. Also, the first generation MSS satellites will have large signal "footprints" which are not compatible with requirements for broadcasting digital map updates and current traffic parameters on a region-by-region basis. However, second generation satellites will employ large, multibeam antennas that will have smaller footprints which will permit multiple frequency reuse (Ref 38).

In Canada, the planning for MSAT (**M**obile **SAT**ellite) has been carried out by Telesat and the Department of Communications (DOC) in consultation with the telecommunications industry, provincial governments, federal departments, communications equipment suppliers and prospective users. MSAT is designed to complement services provided by mobile radios and telephones in heavily populated areas where most people are close to base stations. Telesat estimates that 80% of the system use will be for voice communications over mobile radio and mobile telephone; but data transmission (information called from computer databases for display on a small video screen) will also be important. Other expected services include nationwide paging, and broadcasting of weather forecasts and agricultural information to any point in Canada.

The initial system will use only one satellite to provide service to all of Canada. On the ground will be: central station for satellite control and managing communications flow, several 'gateway' stations for connection to the public tele-

phone network, and several hundred base stations to funnel traffic to and from (up to 35 000) mobile radios. Communications with mobile units will be in the 800 MHz band, the up and down links between the satellite and the gateway stations will be at 13 and 11 GHz. It is now expected that MSAT will be launched in 1993, with full scale operation likely to follow within a year or so.

DOC has undertaken several reviews of the utilization of various radio frequency bands by users, and of operational requirements, technological progress and user needs. These have made possible more efficient utilization in general and the sharing of under-utilized spectrum. DOC is currently inviting comments on two discussion papers on spectrum utilization policy:

* Utilization of the Radio Frequency Spectrum in the Range 30.01-890 MHz - September 1987
* Spectrum Utilization Policy (SP 300.89) for the Fixed, Mobile, Radiolocation and Amateur Services in the Band 890-960 MHz - July 1986

  both by:
  Telecommunications Policy Branch / Spectrum and Orbit Policy Directorate / Department of Communications / Government of Canada.

Other essential Canadian source documents on mobile communications are:

* Ontario Communications Handbook 1985
  Ministry of Transportation / Province of Ontario
* Table of Frequency Allocations
  Telecommunications Policy Branch / Department of Communications / Government of Canada / March 1986
* Spectrum Allocations in Canada
  Canadian Government Publishing Centre / Supply and Services Canada / 1982

2.3 SYSTEM COMPONENTS

A concept layout for many general purpose automobile navigation systems currently being developed is presented in Exhibit 8. The major on-board components of virtually all automobile navigation and information systems fall under some combination of the fifteen categories discussed below. No system currently on the market or in the planning phase includes components in all categories - however, the most sophisticated systems in the future well might.

2.3.1 Navigation Sensors

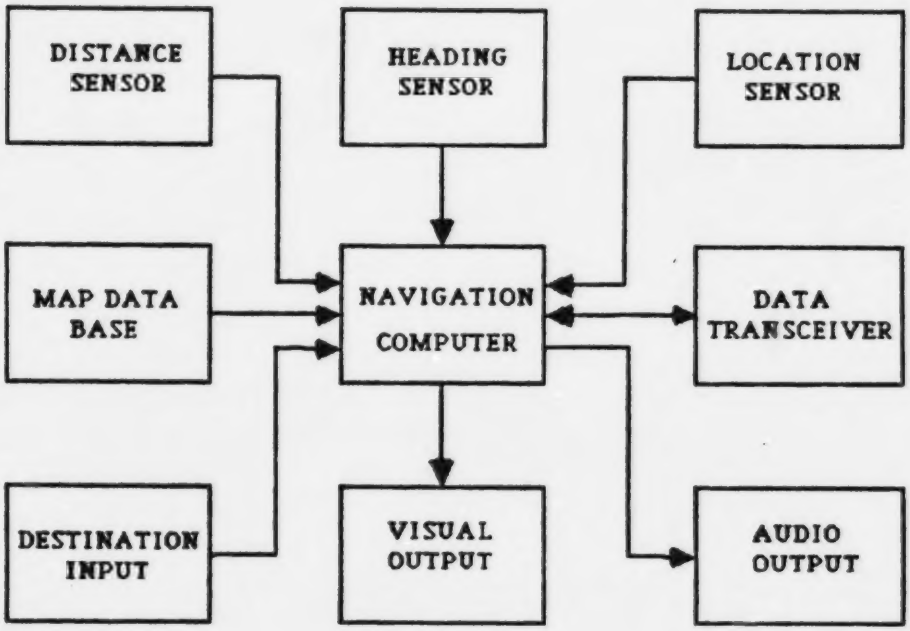
Distance Sensors - Distance measurements are almost invariably performed with some form of the odometer which, in effect, measures the length of track laid down by the perimeter of a wheel in rolling contact the road surface. Odometer technology dates back approximately 2000 years (Section 1.3.2), and the conventional mechanical odometers used in automobiles are typically accurate within 1 to 3 percent of distance travelled. Error sources include tire wear, changes in tire pressure, variations in vehicle loading, the centrifugal expansion of tire radius with increasing speed and tire slippage on road surface.

Electronic odometers, whose calibration may be adjusted by software to maintain higher accuracies, are often used for input to modern navigation systems. Electronic odometers are usually implemented by use of non-contacting sensors which produce discrete electrical signals, each corresponding to small increment of wheel or shaft rotation.

The movement of vehicle relative to a statistically rough road surface can also be determined, without direct contact, by optical means. The moving surface, illuminated if necessary, is projected through a lens onto a sensor grid (eg: photodiode strips) and high speed spectral analysis is used to deduce rate of movement. Such equipment has been used for years as a "fifth wheel" for precise automobile testing. The only known example of such an approach being used for naviga-

EXHIBIT 8

GENERIC SYSTEM CONFIGURATION



Source: Ref 14a

tion purposes is in OKE - an experimental vehicle location system developed by the Robert Bosch Institute (Ref 50). OKE uses this technology for detecting heading changes as well as distance travelled.

Heading Sensors - The underlying accuracy problems of the magnetic compass due to anomalies in the earth's magnetic field are compounded when installed in an automobile. In addition to having a permanent magnetic field of its own, the automobile has induced fields depending upon its heading in the earth's magnetic field, and sub-permanent magnetism may be acquired when going over a bump in one direction, and may or may not be lost in going over another bump. Further, in urban settings, the sensor readings are frequently (albeit briefly) distorted by near-by electrical transformers and overhead tram and trolley wires.

Nonetheless, modern versions of the compass are included in many automobile navigation systems. The flux-gate type of compass is well suited because its output is in the form of electrical signals, and software calibration techniques may be used to ameliorate the perturbing effects of the automobile itself. The flux-gate compass consists of two coils orthorganally wound around a highly permeable core material. A third coil carries an alternating current which excites the core and induces alternating voltages in the orthorganal coils. Superimposition of the earth's steady magnetic field produces a phase shift in the induced voltages which is dependent upon the orientation in the magnetic field.

After installation in a vehicle, calibration is accomplished by rotating the vehicle through 360 degrees and logging the variation between indicated and actual directions. This provides a basis for using software to compensate for the effect of the vehicle's magnetic properties on subsequent compass readings. No reliable (electronic) techniques are as yet available for fully filtering out the effects of near-by transformers and such; however, cross-referencing the compass readings to heading change readings from other types of sensors can reduce the actual errors caused.

Heading Change Sensors - While the magnetic compass is the only self-contained means available for direct measurement of vehicle heading, there are numerous technologies available for measuring changes in heading. These include applications of gyroscopic or inertial principles. Examples used in automobile navigation systems include a fluidic version in which deflections in a helium jet caused by heading changes are detected by cooling effects produced when the deflected helium jet strikes a heated wire grid, and a vibration-rate sensor in which the angular velocity of rotation of a vibrating beam is obtained by detecting the Coriolis force.

Recent developments include a lightweight, compact, optical-fibre gyroscope which uses laser light (split into two beams, polarized and launched into opposite ends of a roughly 500m long coiled, hair-thin glass fibre) and solid state components to sense movement. Most components are integrated on a single optical chip, and the gyro has no moving parts.

The method most commonly used by automobile navigation systems for measuring relative heading changes is the differential odometer; ie. a pair of odometers, one each for the wheels at opposite ends of a common axle (Section 2.1.1.) By measuring the differential travel of opposite wheels, a vehicle's path and heading relative to its starting point may be computed.

While the differential odometer is very sensitive in detecting the occurrence of turns, the accuracy is affected by several error sources in addition to those outlined above for the odometer. Steeply banked turns, for example, are underestimated by the differential odometer, and when installed on the front wheels of a vehicle the steering geometry distorts the wheel separation resulting in turns being overestimated. Differential odometer signals may be derived from the wheel rotation sensors required by anti-lock braking systems (ABS).

2.3.2 Other Sensors

Engine Diagnostics - With the advancement of continuous, automatic engine diagnostics, in-vehicle navigation/information system units can be programmed to store (for future

reference) and/or display (upon request; or immediately, as an over-ride, in case of anticipated failure) the readings and/or interpreted results (ie. source of malfunction), or related diagrams and service instructions. The navigation unit may also continuously record, through the vehicle's own plug-in data channel, such operating information as:

- speeds & acceleration/deceleration (abruptness) & etc
- fuel consumption & time/distance travelled & idling.

The unit could be readily programmed - in addition to automatically recording the driver's identity, date and time - to signal an alarm to the driver in case of a violation of traffic rules. The navigation unit could interpret this by comparing signals from the vehicle sensors with signals from transmitting traffic signs (speed, even parking) or with traffic rules data stored on its digital map. This recording and alarm could also be much more individualized, driver specific, eg: based on special rules developed (and entered) for the family's teenage drivers etc. The unit could also compare accumulated (time & distance) data to an earlier trip plan.

Vehicle Headways - Several devices, which have been designed to increase operating safety and which could readily be incorporated into an in-vehicle navigation unit, are in a preliminary design or testing stage, eg:

- gap radar, to monitor - front & rear headways
  - side distances
- lane position indicator (to maintain vehicle in the middle of a lane).

The readings from these sensors would be evaluated by the unit's microprocessor, and signals transmitted to send an audible alarm to the driver and, in an impending collision, to automatically taper off the accelerator and activate the brakes. Plans, from the mid-sixties, for automated freeways called for such 'automatic pilot' devices to also control the steering, i.e. once engaged to a centre lane automatic chauffeuring system, until a given destination exit started to approach.

Environmental Sensors - The readings from several other sensors, that may come as options with the vehicle itself - or may be installed in the after-market as part of a mobile information system unit - may be incorporated into a total vehicle operations control system. They would monitor:

- road conditions: friction (presence of ice, water)
- climate conditions
  - outside temp & wind & humidity
  - pollution (&pollen) levels
  - compartment comfort (temp&windows)
- security
  - unauthorized entry: hood,trunk,pass cmprtmnt
  - mobile (electronic) baby-sitter signal.

Visual Scanners - Two types of visual scanners, whose image would most naturally be displayed on the navigation unit's screen, are already in advanced development stages:

- perimeter scanning TV camera (blind spots & backing)
- infra-red scanners (night & inclement weather vision).

Other - Other types of sensors that may become part of the most sophisticated mobile information systems would relay information on:

- driver condition
  - drowsiness (no steering corrections)
  - slow or excessive reactions
  - breathalyzer reading (before start)
- medical diagnostics (heart beat pattern, ...), etc.

2.3.3 Microprocessors

Computer - Virtually all on-board navigation systems are controlled, and the actual navigation calculations are carried out, by a microprocessor supported by appropriate amounts of RAM and ROM. Microprocessors selected for various systems range from the Z-80 to the Motorola 68000 depending upon the amount of processing and operating speeds required. Standard, commercially available microprocessors are currently used in virtually every system.

However, future systems may warrant the design of specialty chips in order to increase the graphics processing speed (for smoother turning of map displays) and in order to allow multiuser/multitasking operation - eg: when, by option, the dri-

ver may be requesting route guidance in the form of directional arrows (or audio) only while the screen and keyboard may be simultaneously in use on the back seat for educational or entertainment purposes.

Software - The software required for the operation of a comprehensive mobile information system will include the following:

* system software for: - computer operating system
  - mobile unit <-> car computer interface controller
* applications software for:
  - sensor inputs management
  - position finding
  - optimum route algorithms: minimum time and/or distance, minimum $ (fuel + food + lodgings), maximum comfort, maximum scenery, optimum 'combined experience' (scenery, heritage, museums, etc), etc
  - display generation: video, audio, print, motion
  - display manipulation: zoom levels, quick scan, personalized overlay selection,
  - data base management:
    - on-board: permanent, personally up-dated
    - incoming: upon request only, or automatic upon entering a transmitter's range (options: allow access to all, or filter based on personalized priority criteria, eg: all advertising screened out)
  - automatic record keeping: speeds, driving manner by corridor & by congestions vs non-congestion (accumulated abruptness, accumulated wear&tear, ...), fuel, time vs distance by corridor or fwy section, surrounding vehicle types (presence of transport trucks, traffic act violators, ...),
  - word processing & computing
  - other
    - user programming shell: personalized function codes development, etc
    - automatic pilot (veh control commands)
    - emergency overrides
    - medical systems
    - educational systems
    - entertainment systems
    - general encoder/decoder functions
    - ...

- communications (receiving & transmitting)
  - IR beacons, radio transmitters, ..
  - electronic traffic signs, ...
  - operations control centres
  - traffic control centres
  - community services centres
  - commercial (marketing) units
  - enquiry systems & bulletin boards
  - other vehicles
  - carry-off modules&wands&remote crl
  - office, ..., home
  - ...
- artificial intelligence applications, eg:
  - route optimization for frequent O/Ds
    - selection, based on time available plus traffic conditions plus distances & activity types, of activities from family or business 'cookie jar'
  - interpretations/adjustment to route guidance advise from central control based on:
    - previous experience when followed & when not followed
    - driver's established ability/inability to cope with congestion and other conditions typically found on recommended vs. non-recommended routes.

2.3.4 Data Storage Devices

Large capacity storage, such as Compact Disk - Read Only Memory (CD-ROM) and Digital Audio Tape (DAT), is required for useful amounts of map data. A nationwide digital map would fit on one 500-MByte CD-ROM disc. However, future systems will also need to allocate large amounts of storage to "yellow pages" or other directory type information to aid drivers in performing personal errands and business functions.

CD-ROM is still relatively expensive; the players will have to be made to withstand typical automotive abuse, vibration, impacts, humidity and temperatures from -40°C to +85°C. Also, large amount of map data are generally not yet available for storage. Accordingly, first generation systems typically use high density tape cassettes, RAM, EPROM, etc. for storing modest amounts of map data (eg: Los Angeles area street map). Future systems may use 5¼" erasable optical disks, allowing relatively inexpensive, periodic updating at the local 'vehicle navigation centre'. Future systems may also incorporate a floppy disk drive to provide for easy transferability of

some personal or business data (that needs to be worked on at home, in the office or at a client's base).

2.3.5 Input/Output Devices

Information Display Devices - Information display devices presently used with vehicular navigation systems generally fall in one of two categories; CRTs and simplified display panels. CRTs, used for displaying maps or large amounts of information, come in two basic types: vector and raster scan (both may be color or monochromatic). Virtually all CRT displays used with automobile navigation systems are standard commercially available devices.

Simplified display panels are of LED, LCD, fluorescent or luminescent type. Some are formatted to show a few lines of variable text, while others are designed to show symbolic arrows and shapes to indicate driving maneuvers to be made.

A third type of display that may have potential for future systems is the "heads up" projection display (a laser holograph, but with 2-dimensional projection), already familiar from aircraft applications. This technology may ultimately have a significant impact on what and how much can be displayed while the vehicle is in motion - without jeopardizing traffic safety. While at present the manufacturing costs appear prohibitive, a new holographic lens holds great promise: a thin sheet of plastic laminated to the windshield, which works with the electronic displays already in cars (as opposed to expensive lasers).

The more elaborate future systems will likely also include the use of compact printers for obtaining a 'hard copy' of some instructions (eg: situation summary for operators of emergency vehicles, who have to leave the vehicle while on-site) or specified content of either on-board or external data file (eg: just received in response to inquiry from the vehicle). On-board printers, albeit not as a navigation unit sub-component, are already available - eg: in Finland they are used by taxis, in North America by trucking companies, to print an invoice at a pick-up or delivery site.

Audio Devices - Two different types of audio sub-systems are in use in the current systems:

* one is a simple annunciator which may be a buzzer or a tone generator to draw the driver's attention to information shown on a display
* the other type uses voice to give spoken instructions or information via loud speakers on one of three different voice approaches: pre-recorded messages, digitized voice, and synthesized voice.

Control Consoles - All systems require some means for the driver and/or passengers to communicate with the system - for example, to specify a destination. Many different approaches are illustrated by contemporary systems. Some use push buttons, keypad, or full keyboard arrangements; while others use CRT touch screen controls.

Future systems may incorporate a read/write unit for personalized (or company) optical data cards that could store enormous amounts of vehicle operator (and family) specific information (personal IDs, medical data, digitized pictures, etc) - while also keeping a complete record of every aspect of vehicle operation (for one vehicle or for each vehicle of a fleet). The card could readily control the access to each vehicle or to any limited access site on an individualized (driver) basis. A recent version, roughly the size of regular credit card, promises to hold up to 200 Mbytes of information (with 1/2 second access time to any byte), stored as reflective, laser-made microscopic pits on both sides of the card. A six card data storage unit, which can contain maps for all of North America, could also be developed to operate as the primary data storage device for a navigation unit.

Infra-red remote control devices may also be incorporated to facilitate the use by rear seat passengers (of units that can not be removed from driver console or the dash).

Speech recognition systems hold significant potential as future control devices that will increase the safety of mobile information system operation (ie. when being operated by the driver). Recent developments include a DSP (digital signal processor) chip which yields the performance of earlier large-vocabulary, real-time speech "recognizers" but in an

PC-AT environment. These systems, with the help of artificial intelligence techniques, are beginning to be applied in the industry (eg: quality inspections on a manufacturing assembly line). Special adaptations may be particularly helpful for the handicapped (the equivalent of 'HAL', or the Home Automation Link, and other similar devices on the market). In the automotive environment (as in industrial applications), however, background noise is one challenge that has not yet been fully overcome.

2.3.6 Other Devices

Other on-board devices that will be part of mobile information systems installations are:

- devices to prevent tampering
- self-destruct device - to render all expensive components unusable (& unrepairable) in case of theft, and
- transformer & back-up batteries
- installation equipment
  - sealed cabinets: console/dash & trunk
  - mounting arms with tilt&turn joints
  - connections for other seats
  - antenna casings
  - adapters for disabled
  - special modems & scramblers
  - ...

2.3.7 External Components

Totally self-contained dead-reckoning navigation systems need not include any components that are not on-board, if the purpose is solely location and path finding for that single vehicle. However, if such systems are part of a fleet dispatch/rerouting system - or if they are not fully self-contained - the system would, depending on its type and range of functions, include some of the following external components:

* road side
  - detector/transmitter loops (in guard rail, pavement, ..)
  - proximity beacons
  - electronic traffic & street signs
  - electronic parking meters, gates, ...
  - variable message signs
  - electronic billboards

- cellular grid antennas
- HAR monopole or cable antennas
- CB radio transmtr/receivers (remote sites)
- ...

* ground stations
  - Loran C: master transmitter & slave stations
  - satellite: surveyed receiver to determine correction terms (for differential GPS)

* operations centres
  - network: assign radio channels to mobile and telephone exchanges
  - telephone exchange/control centre

* base stations
  - dispatch office: computer & AVL controller & display/voice console
  - regional & district sales offices, ...
  - ...

* central control
  - traffic: computer & peripherals & consoles & display maps & cassette equipmnt
  - emergency services: police, fire, ambulance municipal hydro&sewers
  - community services: coordination of information from public and private sources (computer & peripherals & modems & etc)

* mobile information services
  - vehicle navigation centre: purchase, maintenance and calibration of navigation units & updating of mass storage
  - plug-in terminals on:
    - line-haul commuter systems (subscription bus, van pools, trains)
    - ...

2.4 INFORMATION CONTENT AND PROCESSING

2.4.1 Digitized Map Data

Digitized maps are as essential to the car navigation systems of the future as paper maps and charts were to the professional maritime navigators of the past. However, car navigation is only one of many useful applications of digitally-encoded street and road maps. Digital maps enable new approaches to managing spatial information, and the graphically-modelled street and road networks provide the logical framework for organizing files of many types of information associated with specific street segments or locations.

a) Encoding Concepts

There are two basic approaches to digitally encoding maps:

* vector approach applies mathematical modelling concepts to represent key geometrical features such as roadways and boundaries with a minimum of data;
* matrix approach, like a picture, models every grid element of a map, whether relevant or not, and thus requires more data storage.

A comparison of the characteristics of the two encoding techniques is presented in Exhibit 9.

By considering each street as a series of lines and each intersection as a node point, a map may be viewed as a series of interrelated nodes, lines and enclosed areas. The method by which numbers may be assigned to node points representing street intersections is illustrated in Exhibit 10. Node points are also positioned along curves on a given street segment. Curves are thus represented as a series of vectors connecting these node points, just as vectors connect the intersection node points.

The x-y coordinates of node points may manually be established directly from maps of appropriate scale. In practice, they are usually determined by a special digitizing work station which records automatically the coordinates of a

EXHIBIT 9

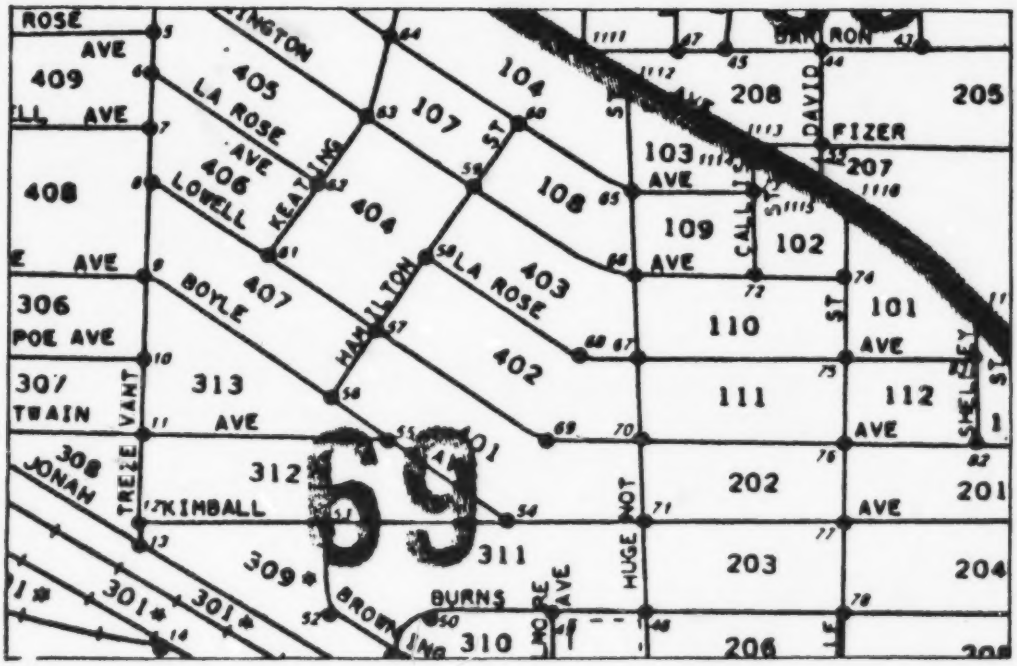
MAP DATA BASE ENCODING

	ENCODING TECHNIQUE	
ATTRIBUTE	VECTOR	MATRIX
FORM	Mathematical model	Tessellated image (= bit-mapped or mosaic)
ADVANTAGES	Compact data set	Regular features
	Facilities matching	Low encoding effort
DISADVANTAGES	High encoding effort	Bulky data set
	Omitted features	Impedes use of map-matching

Source: Ref 15

EXHIBIT 10

NODE POINTS AND STREET SEGMENTS OF VECTOR-ENCODED MAPS



Source: Ref 86

given point when the cross hair of the instrument is placed over the point and a button is pressed.

The node point numbers, if used, are used for logical association purposes, while their x,y coordinates are used for mathematical analysis. The x,y coordinates may be specified in any consistent rectangular coordinate system. Unless already in state plane or latitude-longitude coordinates, the map data set should include the transformation to standard coordinates for facilitating edge-matching with other maps.

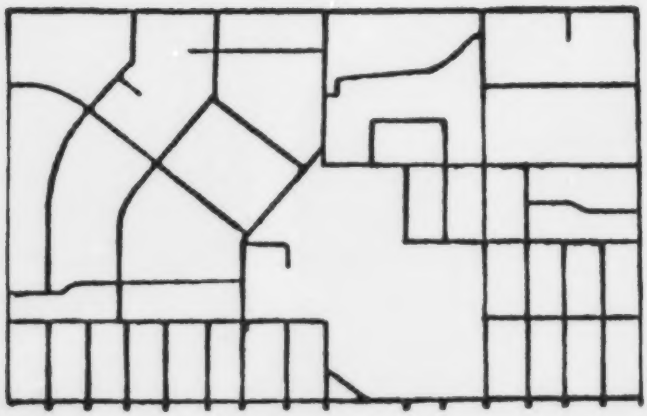
The length and direction of the vectors representing street segments connecting node points may be computed from the node coordinates. A particular route is a unique sequence of vectors and may be defined by the series of node points encountered along the route; the path driven by a vehicle may then be deduced by dead-reckoning techniques. If the vehicle starts from a known location on the encoded map, each successive vector can be compared with the possible vectors from each node point to track the vehicle location. As long as the "measured" profile is within acceptable limits the driven vectors may be matched with the corresponding encoded vectors and position discrepancies removed at each node. This is the principle of the map matching technique described in 2.1.5.

Matrix encoding preserves map detail in a digitized picture form rather than in a mathematically abstracted form. It may be compared to a digitized TV image in which each pixel or picture element, as determined by an x-y grid with arbitrary spacing, is defined by digital data giving characteristics such as shade or colour. Thus, in addition to requiring much more data storage, matrix encoding does not facilitate analytical treatment of logical connections among the map elements.

The Boeing "Flair" vehicle location monitoring system (Ref 56) used a sparse matrix to represent a street map as illustrated in Exhibit 11. The encoding process involves overlaying the map with a grid network having regularly spaced grid elements, and recording a value of 1 or 0 for each grid intersection. If a grid intersection coincides with a street or roadway, a logic 1 is stored for that x,y position. If the

EXHIBIT 11

MATRIX-ENCODED VERSION (ABOVE)
OF A STREET MAP (BELOW)



grid intersection does not overlay a street, a logic 0 is stored.

The upper portion of Exhibit 11 shows the matrix pattern thus generated to digitally represent the map shown below. Note that street positions must sometimes be shifted slightly to correspond with actual grid intersections, as the coarse grid network cannot readily accommodate streets consistently running at an angle, other than parallel to grid lines, or at 45 degrees with respect thereto, and still maintain accuracy. A 110-foot grid increment (approximately 34 m) was found to be sufficient in most metropolitan areas as the typical city block is 330 by 660 feet (approximately 100m x 200m).

As used in the map-matching process of the Flair system installed for the police department at St. Louis, dead-reckoning parameters of vehicles being tracked were communicated to the central system at intervals of approximately one second (Ref 57). The vehicle location was calculated in compatible x-y coordinates and compared with the matrix map data to establish position relative to the map.

By using small mesh sizes, matrix encoding could be used to define a street network to any desired degree of accuracy. However, in addition to heavy data storage requirements for accuracy, the approach suffers from the lack of logical means for associating useful street attributes, such as street name, class of road, address ranges, etc. with specific streets.

b) Data Base Development

Map data base development is a time-consuming and difficult task. Although many aspects, such as digitizing the geometry of road networks may be assisted by automation, the development of digital maps for most purposes also requires compilation and organization of non-mathematical alphanumeric data from a variety of sources. Map data base development is thus an expensive labour-intensive undertaking. For example, Rand McNally & Company estimates that preparation of a United States map data base suitable for car navigation would cost approximately $40-$45 million.

The first large scale map data base development project was undertaken in the public sector. The GBF/DIME System, designed and developed by the U.S. Census Bureau in the 1960s-70s, became the prime geographic processing and coding resource for administering the 1980 Census. It became increasingly useful to agencies at the city, county, regional and state levels during the 1970s. It has since become an important resource for various commercial applications as well.

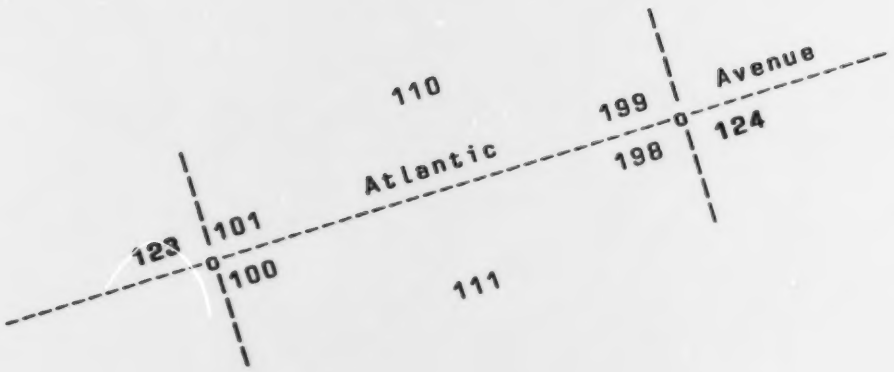
GBF/DIME stands for **Geographic Base Files/Dual Independent Map Encoding** (Ref 86). The term DIME refers to the fact that the basic file is created by defining two independent incidence matrices from the source map: (1) the node point at the end of the line segments and (2) the areas enclosed by the nodes and line segments. The GBF/DIME File, itself, is a computerized version of a street map and contains all features shown on the Census Bureau's Metropolitan Map Series, plus block-by-block address ranges, ZIP codes, and x-y coordinate values at intersections (state, plane, latitude-longitude, and map-set miles).

The GBF/DIME system uses the node and segment concept for vector encoding as illustrated by Exhibit 10. The type of information contained in the file for a single segment, identified by its "from" and "to" nodes, is listed in Exhibit 12. Each record in the file identifies a segment of a feature on the map sheet (Atlantic Avenue), the two node points between which it is located (nodes 123-124), the address range along street features (101-199 on the odd side and 100-198 on the even side), and the geographic units identified on either side of the segment (block, census tract, place, ZIP, etc.).

All SMSA's (Standard Metropolitan Statistical Areas), including approximately 60 percent of the U.S. population, are covered by the GBF/DIME files. The files represent the street network as it existed in 1977, and have numerous errors in segment connectivity. Highways and rural roads are generally not included as the files cover only 16 percent of the U.S. land area. The Census Bureau has recognized these deficiencies, and is preparing a new system called TIGER (**Topologically Integrated Encoding and Referencing System**) - to be completed in time to support the 1990 census.

EXHIBIT 12

EXAMPLE OF GBF/DIME FILE INFORMATION



FOR EACH STREET SEGMENT, A DIME RECORD CONTAINS:

From Node	123
To Node	124
Street Name	Atlantic
Street Type	Avenue
Left Addressees	101 - 199
Right Addressees	100 - 198
Left Block	110
Left Tract	9
Right Block	111
Right Tract	9

Source: Ref 86

c) TIGER System

The term "TIGER file" refers to a computer file that contains all of the data representing the position of roads, rivers, railroads, political and statistical boundaries, and other census-required features along with their attributes, such as name, address ranges, geographic code, feature class, and so forth (Ref 58). The TIGER file, plus the specifications, procedures, computer programs, and related materials required to build and use the file, constitute the TIGER System.

The spatial framework for the TIGER file is being provided through a cooperative program between the U.S. Geological Survey (USGS) and the Bureau of the Census. Each USGS 1:100 000 scale map is being raster scanned and vectorized by USGS to produce four logical computer files:

* roads * hydrography * railroads
* 'other transportation file' - containing, among other things, pipelines and powerlines.

The Census Bureau is tagging the roads file with the seven-character USGS attribute codes. USGS is tagging the other files with similar codes. Then the files are combined at USGS to form their National Digital Cartographic Data Base. From this combined, tagged data base, files of all transportation and hydrography are provided to the Census for use as the TIGER spatial framework.

The TIGER file structure is designed as a series of interlocking files. These are called lists and directories. The lists are characterized by random storage of their elements while the directories have their elements stored in a particular order. Each element can be considered as a record in a list or directory. The elements contain data items and/or index pointers to other elements or to elements in other files. These pointers give the TIGER file-structure its interlocking nature and provide a means for rapid access and management of the total file, both spatially and in more conventional fashions. TIGER will result in an integrated system capable of performing the following three major geographical functions:

1. assignment of residential and business addresses to a geographic location for data collection
2. provision of the geographic structure for tabulation and publication of the collected data
3. production of cartographic products to support data collection and publication operations.

2.4.2 Etak Map

The Etak Navigator (Section 2.1.5) requires map information to update its dead-reckoning display and to compute destination positions. In order to meet the many map requirements of the navigator design, a topologically-structured digital map data base was selected. Such a system defines significant points, lines and areas - along with their incidence relations. Maps structured in this manner can be compactly stored and easily searched, modified and manipulated. Cultural and geographic features can be associated with any data item. Examples include elevation linked to point, street names linked to lines, and terrain features or cities linked to areas.

Etak uses the GBF/DIME file as the primary source of street name and address information. Coordinates are principally obtained from either United States Geological Survey topographical maps, or from aerial photographs. Etak has developed a mapping process which provides approximately a threefold improvement in productivity per mapping-person-hour over earlier techniques.

The Etak map data is within 50 feet (16m) of ground truth as given by U.S. Geological Survey 7.5' quadrangle topographical maps, and has a relative accuracy of 15 feet (5 m) within each map. Etak's claim of 5 m relative accuracy means that corner points defining curves within street segments are positioned such that the street model is at all points within 5 metres of the street centre line.

2.4.3 Navigation Technologies Navigable Database

The value of a digital map database is enormously enhanced when the map is not only descriptive, but also navigable.

"Navigable" means that enough detail is provided on roadway characteristics (eg. carrying capacity, turn restrictions, address ranges, ...) to permit high quality routes to be plotted, given only starting and ending points. Such a computer accessible database becomes the basis to be imagined. Navigation Technologies Corporation (formerly Karlin & Collins Inc) has taken the lead in building a fully navigable, value-added database covering the 100 largest cities in the U.S. and Canada. Once complete, this electronic North American street map will be a unified, 20-gigabyte, continuously maintained online navigable database - accompanied by a comprehensive environment to support and exploit the data resource (Ref 59).

2.4.4 Canadian Experience

The digitization of map data in Canada has been under way now nearly a decade. The Topographical Survey Division/Surveys and Mapping Branch of Energy, Mines and Resources Canada has already digitized - for its 1:50 000 NTS data base - all of Southern Ontario (including Metro Toronto), and expects to have Quebec City-Windsor corridor available early 1989. There is no scale for the data itself, other than what can be identified from the 1:50 000 aerial photography, ie:

- minimum 6mx6m buildings will appear (30mx30m will be plotted to scale)
- churches, schools, etc identified by name/text attached
- all transportation facilities and trails
- drainage / hydrography / bush / ...
- contours at 10m intervals.

Coding scheme and file format which is used to code data is the Intergraph Standard Interchange Format (ISIF). EMR's data is presently raw, or non-relational spaghetti data - ie. there is no structure as such, only pure data points and line strings. Specifications will be ready shortly for structuring the data and for handling adjacency and nodes at linear intersections. The latter effort will be done by semi-automated batch processing, as oppose to introducing them at the time of capturing the data (which is time consuming).

EMR's publication 'Topographic Mapping Manual of Digital Compilation Specifications and Instructions' discusses in detail: digital mapping features, methods, conventions, file colour codes and cartographic editing procedures.

In Ontario, a 1982/83 user needs study (of 4 municipalities and 107 groups in the provincial government) about comprehensive geographical referencing system culminated in a 'Seminar on Land-related Information Systems' (12-13 December 1983), sponsored by Ministry of Natural Resources. Since that time major efforts have been under way in several ministries - namely Natural Resources, Health and recently MTO - to digitize map data. As part of this effort, MNR has published 'Syntactic Structure for Map Data Interchange' - covering the interchange of data for mapping applications.

The Central Mapping Agency of Metro Toronto has developed, and is presently in the process of refining, 1:10 000 digital mapping specifications - which outline levels and graphic data classes for all features to be digitized. While it is also in Intergraph Standard Interchange Format (ISIF) - and not compatible with MNR's Map Data Interchange Format (MDIF) - its permanent feature codes are different from EMR's. Correlation tabulations will need to be developed.

Software development has been also underway to automate the data entry process into three steps (eg: by QC Data in an PC/AT environment) using the following:

1. "scanner", a sophisticated photographic device containing an array of carefully aligned cameras, produces a stylized black-and-white picture of the original map made up entirely of dots
2. "vectorizer" generates digital data, based on statistical guesses about which dots join into lines and how intersecting lines connect (result: digital spaghetti data)
3. "untangler" software allows the user to edit the digital spaghetti map quickly:
   - classify and tag categories of information
   - build up, layer-by-layer, an accurate representation of the original map into the computer's memory.

2.5 FEATURES MATRIX ON CURRENT SYSTEMS

A matrix comparing numerous features of current mobile information systems that include navigation capability has been prepared to provide an overview of the state-of-the-art as of winter 1987-88.

2.5.1 Potential Classification Attributes

Typical system attributes used to classify or describe automotive navigation system features are as follows:

* Navigation Technique
  - Dead Reckoning
    - Odometer
    - Differential odometer
    - Compass
    - Other
  - Proximity Beacon
  - Radio Location
    - Satellite
    - Loran C
    - Other
  - Map Matching
* System Functions
  - Vehicle location
  - Destination location
  - Route guidance
  - Other
* Driver Interface
  - Audio
  - Simplified display
  - Detailed display
* Map Storage
  - Hard copy
  - Image encoded
  - Vector encoded
* Data/Voice Communications
  - One way
  - Two way.

Numerous other attributes may also be used for describing or classifying systems. These include originating organization (industry type or public sector agency), country, year announced, availability on the market, etc. Cost is also a potential means for classifying systems; but too few systems are actually on the market to make it a meaningful classification attribute at present.

2.5.2 Classification Scheme

An established classification scheme given in EUCO COST 30 bis (Ref 61) basically sorts systems according to their infrastructure relationship. Stephens (Ref 62) used the same scheme in a recent compilation of some 40 systems, not all of which had navigation features. The same scheme is incorporated in the broader scheme selected for the features matrix in this report:

Class	Description	Communication Linkage
* Class 0 -	Self-contained vehicle systems	None
* Class 1 -	Area broadcasting	One-way to veh
* Class 2 -	Local roadside transmitter	One-way to veh
* Class 3 -	Mobile radio systems	Two-way
* Class 4 -	Local roadside transponder	Two-way.

Another classification method used in the matrix is the navigation technique employed:

* DR - Dead reckoning of all types
* PB - Proximity beacons including loops, short range RF, infra-red
* RL - Radio location which includes LORAN-C and satellite approaches
* MM - Map matching which may be used to enhance any of the above technologies by digital map correlation.

Navigation and route guidance systems are also classified by their function:

* LO - Location coordinates of vehicle indicated or transmitted
* DDD - Direction and distance to destination indicated
* PPI - Plan and position indication of vehicle and destinction on map display
* RG - Route guidance instructions in real time direct driver to destination.

The map formats used by the vehicular systems are classified as follows:

* H - Hard copy
* M - Matrix image in digitized form
* V - Vector network in digitized form.

The map storage medium is also used in classifying the systems (erasable CD, such as Tandy's Thor-CD, has not yet been included):

* RAM - Random access memory (including ROM)
* MT - Magnetic tape cassette or cartridge
* MD - Magnetic disc
* VD - Video disc
* CD - Compact disc
* DAT - Digital audio tape.

The type of visual display used by the systems to convey information to the driver is also used for classification:

* CRT - Cathode ray tube
* LCD - Liquid crystal display
* LUM - Fluorescent, electroluminescent, etc.

Audio output, which may be used to supplement visual output, or used in lieu of visual output, falls in two categories:

* A - Annunciation signal (chime, tone, etc.)
* V - Voice (recorded, digitized or synthetic).

Driver inputs such as operating mode, destination, route selection parameters, display selection, etc. are made through input and display consoles via:

* KP - Key pad, push buttons or other switches
* KB - Conventional key board
* TS - Touch screen (CRT)
* VR - Voice recognition.

Finally, the systems are classified according to their potential applications:

* TA - Travel Advisory
* FM - Fleet Management
* TM - Traffic Management
* MO - Mobile Office
* OA - Occupant Activities
* VC - Vehicle Control.

2.5.3 Mobile Information Systems Matrix

The features matrix (Exhibit 13) includes all known systems that have been demonstrated or announced during the period 1980-87. Each system listed has actually undergone at least some degree of physical development and/or testing, even if limited to important subsystems. Systems that exist only in the form of an idea were excluded. The few systems that are, or have been, actually available on the market are indicated by bold type. Most systems exist only in the form of a prototype or test version; many were developed solely for research and evaluation purposes, and a production version is not necessarily planned.

The 'references and notes' column identifies a source of published information for most systems - and, in some cases, provides further system characterization. The reference publication dates (see Appendix A) give some clues on when each system was introduced. In the few cases where no reference is given, the estimated introduction date is listed instead.

Note that some systems have two or more entries in the same feature category. For example, Philips CARIN system presently operates on an autonomous basis relative to infrastructure (Class 0), but the design calls for an RDS receiver for area broadcasts of traffic data (Class 1) when this information becomes available. Numerous systems incorporate more than one navigation technology.

It should also be noted that the available descriptive material for all systems is not necessarily complete, and that interpretations or estimates were required for some system features.

EXHIBIT 13

FEATURES OF CURRENT SYSTEMS

SYSTEM IDENTIFICATION	INFRASTRUCTURE RELATIONSHIP					NAVIGATION TECHNOLOGY				SYSTEM .FUNCTION.				MAP FORMAT			MAP ....STORAGE.....						VISUAL. DISPLAY			AUDIO OUTPUT		INPUT & .CONTROL..				POTENTIAL .....USE.....						REFS AND NOTES
	0	1	2	3	4	D R	P B	R L	M M	L O	D D	P P I	R G	H	M	V	R A M	M T	M D	V D	C D	D A T	C R T	L C D	L U M	A	V	K P	K B	T S	V R	T A	T H	F M	M O	O A	V C	
AVLS Magnavox	X			X		X		X		X	X													X				X					X					63
Car Pilot Robert Bosch	X					X					X													X				X			X							63
City Pilot VDO Adolf S. AG	X					X					X													X				X			X							63, b
Driver Guide Nissan Mtr Co	X					X					X														X			X				X						54a
Electro GyroCtr Honda R&D Co	X					X				X		X		X									X					X			X							55
ElectroMultiVan Toyota Motor Co	X					X				X	X	X			X					X			X					X		X	X			X				80
Navicom Toyota Motor C	X					X					X														X			X				X						64
Navigator (L) Etak, Inc.	X					X		X		X	X	X			X			X					X					X				X						14
Navigator (C) Etak, Inc.	X			X		X		X		X	X	X			X			X					X					X				X		X	X			65, j
ALI-SCOUT W German Group					X	X	X		X				X		X		X							X			X		X				X	X				24, a
Autoguide U.K. Dep of Tr					X		X						X											X			X		X				X	X				25
AVL 2000 Univ of Calgary	X							X		X		X	X		X				X				X							X			X					73,c
CARIN Philips Intern.	X					X			X	X		X	X		X						X		X				X			X			X					41
CARIN-II Philips Intrntnl	X	X				X			X				X		X						X			X			X			X			X					42
CLASS Chrysler Corp	X					X		X		X		X			X					X			X									X						32, c
Trip Monitor Ford Motor Co	X					X		X		X		X			X						X		X									X						31, e

Note: Systems indicated in bold are or have been commercially available.

EXHIBIT 13

FEATURES OF CURRENT SYSTEMS

(continued)

SYSTEM IDENTIFICATION	INFRASTRUCTURE RELATIONSHIP					NAVIGATION TECHNOLOGY				SYSTEM FUNCTION				MAP FORMAT			MAP STORAGE						VISUAL DISPLAY			AUDIO OUTPUT		INPUT & CONTROL				POTENTIAL USE						REFS AND NOTES
	0	1	2	3	4	DR	PB	RL	MM	LO	DD	PI	RG	H	M	V	RAM	MT	MD	VD	CD	DAT	CRT	LCD	LUM	A	V	KP	KB	TS	VR	TA	TM	FM	MO	OA	VC	
Delco Navicar General Motors	X					X			X	X	X	X				X					X		X						X			X						14, g
Nav Test Car General Motors	X					X		X		X		X				X	X						X						X			X						29, f
EVA Blaupunkt-Werke	X	X				X			X				X			X	X				X			X			X		X			X	X					43, d
Travel Pilot Blaupunkt-Werke	X					X			X	X	X	X				X					X		X						X			X						14, p
Mazda Map Match Mazda Motor Crp	X		X			X	X		X	X		X				X					X		X							X		X						('87)
Telecom Van Mazda Motor Co	X			X				X													X													X	X			67, o
Mitsub GPS Nav Mitsubishi Elctrc	X					X		X		X		X				X					X		X									X						34,c
Mitsub Map Match Mitsubishi Elctrc	X		X			X	X		X	X		X				X			X				X									X						('87)
MAPIX Nippondenso Co	X					X				X		X			X	X	X	X					X							X		X						64, h
MAPIX-I Nippondenso Co	X					X				X		X			X			X					X							X		X						44
MAPIX-II Nippondenso Co	X					X	X			X		X				X	X						X							X		X						44
MAPIX-III Nippondenso Co	X		X			X	X	X	X	X		X	X		X	X					X		X				X		X			X	X					44, i
Micropilot W Jeffereys plc	X					X							X			X			X								X		X			X						53
NEC Navigator NEC Home Elctrncs	X		X			X	X		X	X		X				X			X				X									X						('87)

EXHIBIT 13

FEATURES OF CURRENT SYSTEMS

(continued)

SYSTEM IDENTIFICATION	INFRASTRUCTURE RELATIONSHIP					NAVIGATION TECHNOLOGY				SYSTEM FUNCTION				MAP FORMAT			MAP STORAGE						VISUAL DISPLAY			AUDIO OUTPUT		INPUT & CONTROL				POTENTIAL USE						REFS AND NOTES
	0	1	2	3	4	DR	PB	RL	MM	LO	DD	PI	RG	H	M	V	RAM	MT	MD	VD	CD	DAT	CRT	LCD	LUM	A	V	KP	KB	TS	VR	TA	TM	FM	MO	OA	VC	
Delivery Van Nissan Motor Co	X							X		X		X			X				X				X					X				X		X	X			66, k
GPS Nav Nissan Motor Co	X			X		X		X		X		X	X			X					X		X							X		X	X		X			33, l
Nissan NAV Nissan Motor Co	X					X			X	X		X	X			X	X						X					X				X						46
Nissan New Nav Nissan Motor Co	X					X			X	X		X				X	X						X					X				X						46
Routenrechner Daimler-Benz AG	X					X					X		X			X	X							X				X				X						54, m
Sanyo Navigator Sanyo Electric	X		X			X	X			X		X				X					X		X					X				X						('87)
Sumitomo M-007B Sumitomo Elctrc	X		X			X			X	X		X				X	X						X					X				X	X					45
Sumitomo M-007A Sumitomo Elctrc	X			X		X			X	X		X				X					X		X									X		X				45, n
Yazaki Navigator Yazaki Corp	X					X			X	X		X				X	X						X					X				X						47

NOTES FOR EXHIBIT 13

a. Uses two-way infrared data communications with roadside beacons.

b. Uses optical wand to read locations and destination information from special maps.

c. Uses Navstar GPS for radio location.

d. Prototype uses ROM for map storage; production model will use CD.

e. Uses Transit satellite system for radio location.

f. Uses both Loran-C and Navstar GPS for radio location.

g. Licensed version of Etak's Navigator.

h. Two versions: one used matrix map data on tape, the other used vector map data in RAM.

i. Uses Navstar GPS for radio location; uses matrix encoded map data for background, and vector encoded data for road network.

j. Commercial version of Etak's Navigator with automatic vehicle location and mobile data terminal features.

k. Uses Loran-C for radio location; floppy disk contains delivery itinerary as well as map.

l. Uses Navstar GPS for radio location.

m. Provides explicit route guidance on highway network, and given distance and direction to destination when operating on city streets.

n. Commercial version of Sumitomo's Navigator with automatic vehicle location feature.

o. Uses Navstar GPS for radio location.

p. Licensed version of Etak's Navigator.

2.5.4 System Specifications and Configurations

Formal specifications are not generally available for automobile navigation systems because most are in a early development stage (very few are actually on the market). However, in many cases, system configuration diagrams are available: representative sampling of specifications and configurations available for systems listed in Exhibit 13, is presented by Appendices B.1 through B.8 as follows:

Appendix B.1 - Etak Navigator

Appendix B.2 - Nissan Delivery Van

Appendix B.3 - Ford Tripmonitor

Appendix B.4 - Mapix III System

Appendix B.5 - Philips Carin

Appendix B.6 - Toyota System

Appendix B.7 - Yazaki System

Appendix B.8 - Mitsubishi System

3. HUMAN FACTORS CONSIDERATIONS

3.1 INTRODUCTION

Recent technological advances of visual displays have resulted in the incorporation of sophisticated information display and control systems in automobiles. Much of the technology appears to have been adapted from the aircraft industry, without sufficient regard to the differences in the capabilities and behaviour of typical operators (drivers vs pilots), and in the operating circumstances (road vs air). A detailed investigation into the safety and human factors considerations of mobile information display and control systems is necessary in order to develop design criteria, guidelines, standards and regulations before these devices can be implemented safely for use in automobiles.

The information display and control issue is a systems design issue and requires very delicate systems safety trade-offs. It should be the duty of automotive manufacturers to demonstrate, based upon sound scientific experimental practices, that new sophisticated display systems for automobiles are at least as safe as the "old car" with a speedometer, odometer and gas gauge. Any additional displays and/or controls should not decrease the overall safety of the driver-vehicle-environment system.

The following sections characterize human processing and driving capabilities, man-machine interface considerations, and give examples of interface approaches tried in systems developed in the United States, Europe and Japan.

3.2 PROCESSING CAPABILITIES

3.2.1 The Human Processor

Card, Moran and Newell assert that humans are limited in their abilities to cope with a task (Ref 103). However, it is not easy to determine the exact limiting factor. Card et al

have modeled the "Human Processor", suggesting that it is made up of three sub-processors (Exhibit 14), the:

* perceptual processor
* motor processor
* cognitive processor.

These three sub-processors each require a finite amount of time to process a piece of information but it is relatively unknown whether they act in a serial manner or in a parallel manner. A range of times as well as a mean time for each of the processors to act on a piece of information are also presented in Exhibit 14.

The amount of information processed versus the amount of information presented for a human as an information processor, may also be represented graphically (Exhibit 15). Ideally, of course, the information processed should be equal to the information presented; when overloaded with information, errors and omissions occur until a point of breakdown is reached.

The mental and physical processes of a human have a large effect upon driving performance. Card et al present a postulate known as the "Uncertainty Principle" (Ref 103) which states that the decision time T increases with uncertainty about a judgment according to the relationship:

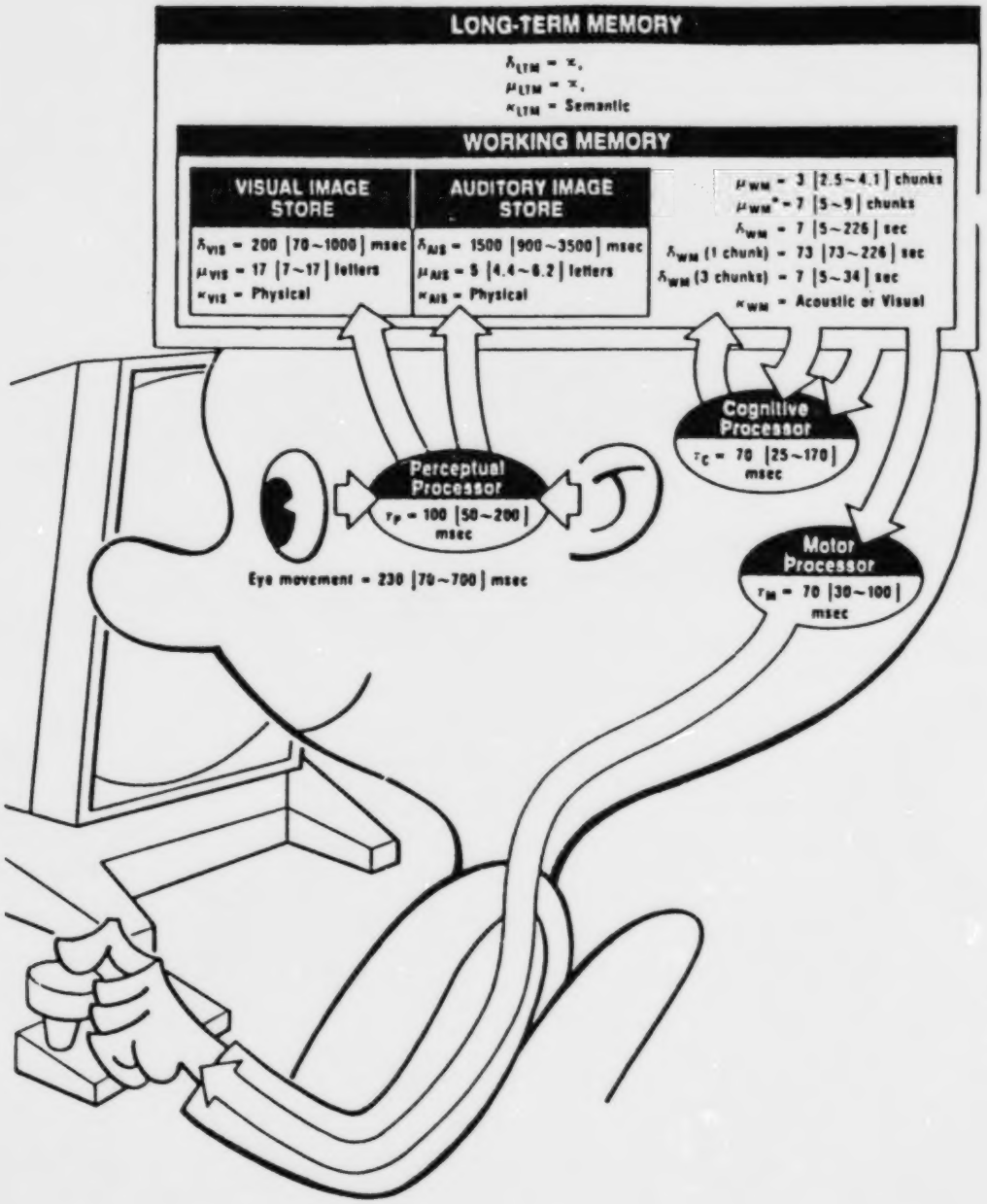
$T = I_c H$, where:

$H = \log_2 (n+1)$	for n equally probable events
$H = \text{sum } [p_i \log_2 (1/p_i + 1)]$	for n events of different probabilities (p_i)
$I_c = 150$ msec/bit	approximately.

Thus, the time required to decide upon 10 equally probable events is approximately 0.5 seconds - but after a decision is made, a reaction to the decision is required and this increases the total time. The choice/reaction time, as a function of the amount of information to be processed, is presented in Appendix C.1.

EXHIBIT 14

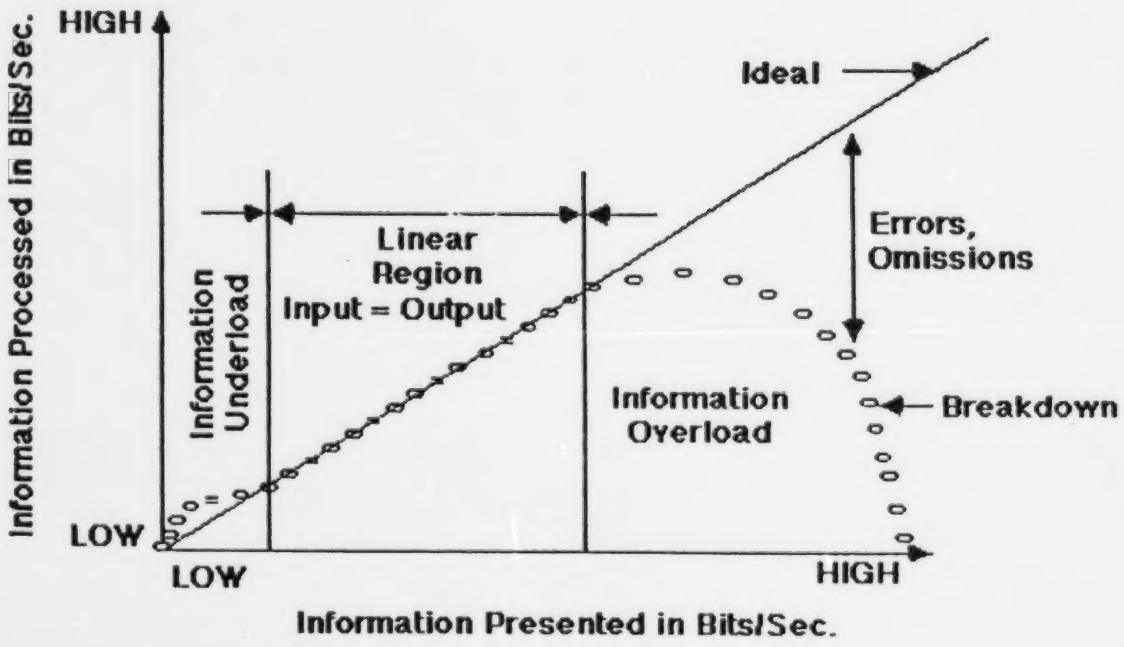
THE HUMAN INFORMATION PROCESSOR


LONG-TERM MEMORY
δ_{LTM} = ∞,
μ_{LTM} = ∞,
κ_{LTM} = Semantic
WORKING MEMORY
VISUAL IMAGE STORE
δ_{VIS} = 200 [70~1000] msec
μ_{VIS} = 17 [7~17] letters
κ_{VIS} = Physical
AUDITORY IMAGE STORE
δ_{AIS} = 1500 [900~3500] msec
μ_{AIS} = 5 [4.4~6.2] letters
κ_{AIS} = Physical
μ_{WM} = 3 [2.5~4.1] chunks
μ_{WM}* = 7 [5~9] chunks
δ_{WM} = 7 [5~226] sec
δ_{WM} (1 chunk) = 73 [73~226] sec
δ_{WM} (3 chunks) = 7 [5~34] sec
κ_{WM} = Acoustic or Visual
Cognitive Processor
τ_C = 70 [25~170] msec
Perceptual Processor
τ_P = 100 [50~200] msec
Motor Processor
τ_M = 70 [30~100] msec
Eye movement = 230 [70~700] msec

Source: Ref 103 (Card et al, 1983)

EXHIBIT 15

CONCEPTUAL MODEL OF THE HUMAN
AS AN
INFORMATION PROCESSOR OR UNCERTAINTY RESOLVER



Many of the new automotive display devices are actually used for both information output and as a control device. From a human factors standpoint, they can be addressed in the same manner as other vehicle control devices. Fitt's Law states that the time T_{pos} to move the hand to a target of size S which lies a distance D away is given by:

$$T_{pos} = I_m \log_2 (D/S + 0.5)$$

where $I_m = 100$ [70 - 120] msec/bit

Therefore, it would take approximately 0.44 seconds to reach a 1/2 inch (1.3 cm) target that is 10 inches (25 cm) away. Note that this is just the time required to reach the object at that distance, and that the time T_{pos} does not consider the perceptual or cognitive processing times. The designer must consider both the size of the control device and the distance between the operator and the control so as to minimize the time required to reach a control.

3.2.2 Age, Alcohol and Drug Effects

Age, alcohol and drugs all tend to adversely effect the processing capabilities of a human. Moraal claims that aging causes a slowing of behaviour which is for the most part due to a lower signal-to-noise ratio. This is to say that as a person ages, the strength of the signals that are sent to the cognitive processor become weaker. Thus, since the signal is weaker, a larger amount of time is required to illicit a response from the person (Ref 116).

Alcohol and drugs act in a similar manner. Zwahlen performed a study where the response uncertainty/choice reaction times were measured for 12 subjects who were not under the influence of alcohol - and then for the same 12 subjects under the influence of alcohol at a BAC (Blood Alcohol Content) of approximately 0.10%. When the subjects were sober they had an average response uncertainty/choice reaction time of 0.83s; but when under the influence of alcohol they had a response uncertainty/choice reaction time of 0.88s. It is expected that higher BAC values would result in even further degradation in reaction time. (Ref 130)

3.3 DRIVING CAPABILITIES

3.3.1 Driving Capabilities and Safety Considerations

McCormick and Sanders illustrate that approximately 55% of all traffic accidents are due to human error alone and that an additional 30% can be attributed to a combination of human error and environmental factors (Ref 114). Human behaviour is most susceptible to error and greatly influences the man-machine interaction. Automotive systems should be designed primarily considering both the physical and mental capabilities of the human.

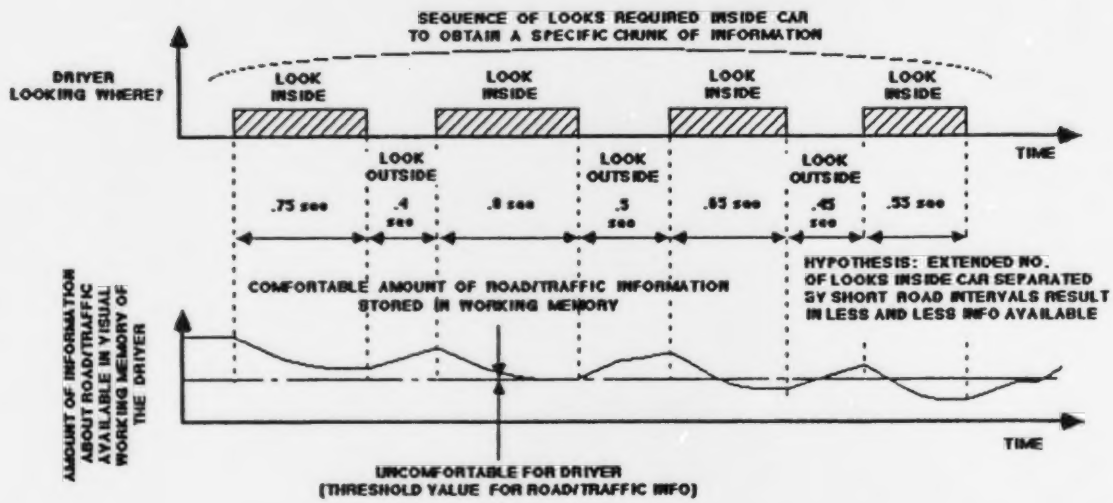
Visual information is the most important aspect of a driving task. The driver is responsible for processing visual information which is both external and internal to the vehicle. The time sharing of visual information has its largest error effect upon tasks which have a greater amount of uncertainty and which depend upon short-term memory according to McCormick and Sanders (Ref 114). A conceptual model for an information acquisition task is presented in Exhibit 16. Note the hypothesis that less and less information is available to the driver with the increase in looks. This result was observed by Zwahlen in a study involving subject response to unexpected windshield wiper failure Ref 128). There seemed to be a stress related visual "after effect" caused by the sudden wiper failure even after the use of the wipers was returned. This "after effect" was probably due to the stress associated with the lack of information available to the driver during the wiper failure.

External visual information has priority in a driving task based on the research of Zwahlen who states that "in order to maintain proper direction and lateral vehicle position on the road the driver must make a continuous string of eye fixations ahead of the car" (Ref 125). This statement reflects earlier research in which x-y density plots of the driver's eye fixations were determined using a corneal reflection technique (Ref 126 & 129). Note Appendix C.2.

It has been documented by research (eg: Appendix C.2) how important it is that the driver maintain visual contact with

EXHIBIT 16

CONCEPTUAL MODEL FOR DRIVER INFORMATION ACQUISITION AND STORED RELEVANT DRIVING INFORMATION [1


SEQUENCE OF LOOKS REQUIRED INSIDE CAR TO OBTAIN A SPECIFIC CHUNK OF INFORMATION
DRIVER LOOKING WHERE?
LOOK INSIDE
LOOK INSIDE
LOOK INSIDE
LOOK INSIDE
TIME
LOOK OUTSIDE
LOOK OUTSIDE
LOOK OUTSIDE
.75 sec
.4 sec
.8 sec
.5 sec
.65 sec
.45 sec
.55 sec
COMFORTABLE AMOUNT OF ROAD/TRAFFIC INFORMATION STORED IN WORKING MEMORY
HYPOTHESIS: EXTENDED NO. OF LOOKS INSIDE CAR SEPARATED BY SHORT ROAD INTERVALS RESULT IN LESS AND LESS INFO AVAILABLE
AMOUNT OF INFORMATION ABOUT ROAD/TRAFFIC AVAILABLE IN VISUAL WORKING MEMORY OF THE DRIVER
TIME
UNCOMFORTABLE FOR DRIVER (THRESHOLD VALUE FOR ROAD/TRAFFIC INFO)

1) When obtaining a specific chunk of information in four intermittent looks from a sophisticated in-vehicle display or When operating a sophisticated in-vehicle control requiring four intermittent looks.

the roadway and that diversions of the driver's attention into the vehicle should be minimized to ensure proper and safe lateral control.

Other factors that influence the driver's visual information that are external to the vehicle are: the time of day and the location of an object to be detected in the visual field. Zwahlen concluded that there is a lower margin of safety during nighttime driving than during daytime driving. This is due to the reduction in the foveal preview distance of the driver during nighttime driving (Ref 126). Another study also showed that a driver's peripheral vision is very limited, at best, for detecting a single object in the peripheral field of view and is almost non-existent for detecting multiple objects in the peripheral visual field (Ref 123). Kantowitz and Sorkin state that even when a target is located in the foveal field of vision during a fixation, objects in the background tend to have a deleterious effect on target detection and reaction time (Ref 112).

Visual information which is internal to the vehicle is also important for maintaining venicle safety. However, the eye does have a finite accommodation time as pointed out by Gramberg-Danielsen who determined that the time involved for a driver to move his/her point of visual fixation from a position 20 m outside the vehicle to the speedometer on the dashboard, and for the lenses to accommodate on this new fixation, was approximately 0.4-0.8 s for persons under 40 and approximately 2.0-2.7 s for persons above 60 (Ref 107).

Combining these results with those of Zwahlen (1986) we find that if a 60 year old person were driving a 6ft wide (183cm) vehicle in a 10ft (3m) wide lane at 30 MPH (48 km/h) and that person moved his/her eye fixation from the roadway to the speedometer, then the probability of that person laterally deviating out the lane during this accommodation time would be between 1.25% and 3.0%. These probabilities do not consider the time to read the information and to refixate (and accommodate) on the driving task on the road ahead. Thus, it is of utmost importance to minimize the time spent fixating on information presented inside the vehicle.

A summary of eye scanning results, which are related to the #attentional demand placed on a driver, as determined in four different studies is presented in Appendix C.3.

Senders et al also found that a driver needs a minimum of 0.25 seconds of highway viewing time to obtain a sufficient amount of information to maintain control of the vehicle and that a viewing time of 0.5 seconds provided the driver with nearly all the available information. In fact, an increase viewing time to 1.0 seconds provided the driver with very little additional information (Ref 119). This is illustrated in Exhibit 17.

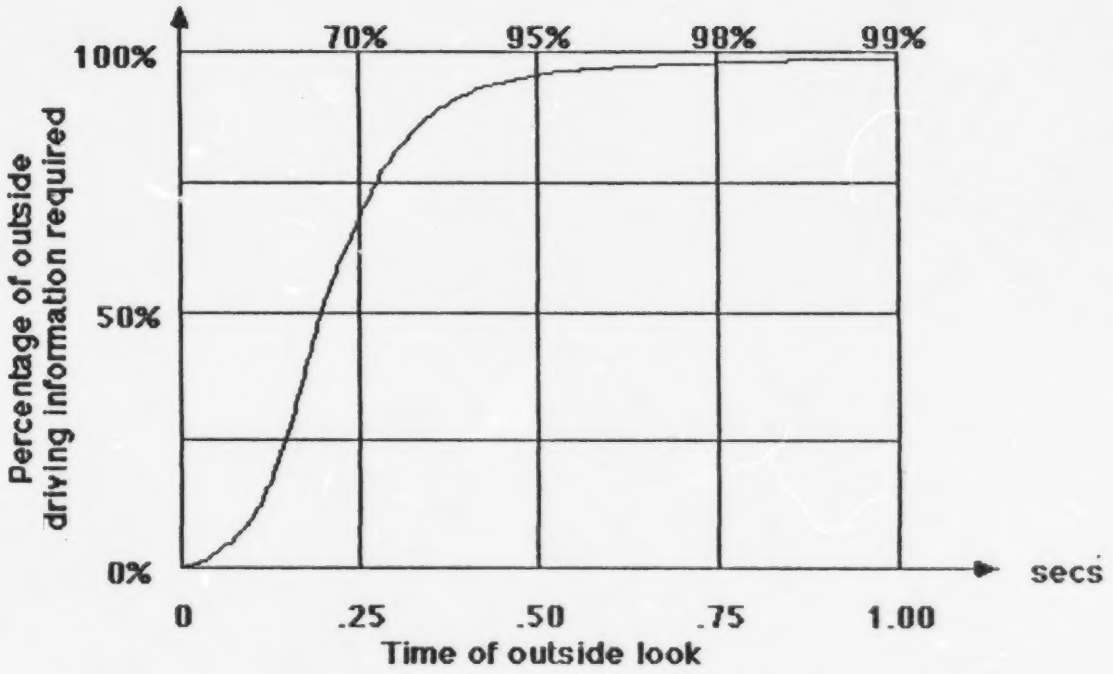
3.3.2 Human Capabilities and Limitations

Major human capabilities and limitations related to driving can be summarized as follows:

1. single channel processor
2. limited information acquisition and processing capacity
3. limited acuity in peripheral visual field
4. finite accommodation speed of lens
5. influenced by age, alcohol, drugs
6. time delays in neural system
7. finite speed for movements (controls)
8. influenced by glare, level of illumination, wave length, dark adaptation
9. influenced by emotions, fatigue, boredom
10. driver expectancy framework, risk-taking behaviour.

EXHIBIT 17

HIGHWAY VIEWING TIME REQUIRED BY A DRIVER TO OBTAIN A CERTAIN PERCENTAGE OF REQUIRED DRIVING INFORMATION



3.4 MAN-MACHINE INTERFACES

Most of the new devices are also under the control of some type of microprocessor. Therefore, the interaction between the human and the computer is an important design consideration. Mitchell et al state that ".. systems must address the problem of providing interfaces between the human and computer which facilitate the human's ability to interact with the system in a rapid and effective manner with as little effort as possible" (Ref 115). Every device used on an automobile, regardless of the type, must be designed such that a maximum number of people can use it with little or no difficulty. The interface between the man and machine can be broken down into two sub-categories, the output interface and the input interface; and they will be discussed in this manner.

3.4.1 Man-Machine Output Interfaces

When discussing the possible information output interfaces between the human and the automobile (or automotive computer), two methods of presentation are basically used: visual presentation method and aural presentation method. One could argue that there is a third information presentation method in the form of a tactual presentation - however, a discussion of this will be deferred to the input interface section.

When discussing the manner in which to relay some information to a driver, most generally a visual presentation is thought of first; but a visual display may <u>not</u> be the best mode of transmission for some information. Simmonds and Galer (Ref 121) introduce guidelines which indicate that a visual presentation should be used if the:

1) message is complex
2) message is long
3) message needs to be referred to later
4) message deals with location in space
5) message does not call for immediate action
6) auditory system of the person is over-burdened

7) receiving location is too noisy or the person can remain in one position.

A possible alternative or supplement to visual displays is the use of auditory information presentation. The beep heard when the keys are left in a vehicle's ignition is an example of auditory information presentation. Simmonds and Galer (Ref 121) explain that auditory presentations should be used if the:

1) message is short
2) message is simple
3) message will not be referred to later
4) message deals with events in time
5) message calls for immediate action
6) visual system of the user is overburdened
7) receiving location is too bright or dark-adaptation is required
8) the person does not remain at the same location relative to the display.

a) Man-Machine Output Interfaces - Visual

If it is determined that a visual presentation method is best suited for use in a particular application, then the best format for the information must be determined. The basic types of display formats are quantitative, qualitative (including status and warning lights), alphanumeric and representational displays. Many times a single display is used to present a combination of two or more of the basic formats which seems to be the case with most of the sophisticated displays that are presently being introduced.

Quantitative displays present a numerical value of some variable. A digital speedometer is an example of this type of display which is being utilized by several vehicle manufacturers at the present time. Digital presentation of the numerical value is preferable if precise values are required and if the values remain visible long enough to be read. Simmonds and Galer (Ref 121) state that 15 minutes of visual arc is the optimum subtended angle in electronic displays for the character size. Under adverse conditions this may be even

greater and the designer should account for this. Mourant claims that the blur and contrast effects are insignificant at approximately 27 minutes of visual arc (Ref 117). McCormick and Sanders state that if the display has an analog nature, that is to say that a scale and pointer are used, then the scale should have markers for the degree of accuracy to be obtained (Ref 114). They also state that the scale labels should progress by 1's or 5's or multiples thereof such as 1, 2, 3 or 10, 20, 30 and pointers should not obstruct the view of the person trying to read the scale.

Qualitative displays are used to present an approximate value for some continuously changing variable. An example of this type of display is a temperature gauge for an automobile engine which informs the driver if the engine temperature is "cold", "normal" or "hot". These displays can take many forms but Wozniak et al found that a vertically formatted display with vertical bars the length of which indicated the engine status is the best when compared to a circular formatted display or a vertically formatted display with a moving pointer (Ref 122). If a display is used for check reading then the desired operating range should be indicated on the display. This applies to a panel of displays also - but, in addition to this, all the pointers should be formatted such that they are all in the same position in the normal range of operation. This helps the operator to reduce errors in reading the displays.

McCormick and Sanders explain that if a qualitative display is used as a status or warning light then the operator should consider using coloured lights, flashing lights and determine the proper foreground-to-background luminance ratio (Ref 114). They suggest that red be used to signal danger, a flash rate of 3 to 10 per second and a foreground to background ratio of 2:1. Green gives several guidelines for the use of qualitative displays in automobiles (Ref 108). These include using displays that increase upward or to the right, labeling the normal operating range with either the words "normal" or "OK" and using bar type displays rather than numeric displays. Other guidelines are also given.

Alphanumeric displays are intended to be used to relay written messages. The effectiveness of these displays is based upon the user's ability to interpret the written message. Mourant found that response times varied from a maximum of 5.7 seconds using small 0.23 cm letters at a contrast ratio of 1.25:1 to a minimum of 1.5 seconds using large 0.84 cm letters at a contrast ratio of 25:1 (Ref 117). Therefore the stroke width, font, width-to-height ratio and size of the letters must be carefully selected. A stroke width of 1:8, a MIL-M-18012B font or San Serif font, a minimum width to height ratio of 3:5, a character size of 0.2 inches (0.5 cm) to be read at 28 inches (71 cm), and the use of capital letters are suggested by McCormick and Sanders. Simmonds and Galer (Ref 121) suggest that the brightness of electronic displays should be adjustable in a range of 500 to 60 000 lux, and the displays should have sufficient contrast to insure easy readability.

Representational displays are used to convey pictorial or symbolic information such as a map. These displays are the most likely candidates for future use by automobile manufacturers but very little information regarding their use is available. Buick has already introduced a "Graphic Control Center" (GCC) in their Riviera model. McCormick and Sanders state in general that a moving object on a fixed background should be used in these displays and that unnecessary detail should be avoided.

Visual coding of information is an important consideration for any of the described types of displays, especially colour coding. Krebs (Ref 113) explains that colour coding is helpful if the:

- display is unformatted
- there is a high symbol density
- operator must search for relevant information
- symbol legibility is degraded
- colour code is logically related to operator task.

ISO Standard 2575 designates that for warning lights, colours are to be used in the following manner:

- Red -> danger to a person or very serious damage to equipment is immediate or imminent
- Yellow -> caution, vehicle system malfunction, danger in vehicle likely or hazard
- Green -> safe, normal operation
- Blue -> driving beam (high) only
- White -> other conditions.

Simmonds and Galer state that colour should be used to group displays but caution the designer not to use red-green or yellow-blue pairs (Ref 121).

Visibility of a display is also important as pointed out by Simmonds and Galer (Ref 121). They explain that for good visibility a display should be laid out such that the plane in which the displays lies is perpendicular to the line of sight, the driver's view should be unobstructed by the steering wheel etc, and the distance between displays should be minimized to reduce eye movements. They are also quick to caution however that some displays should be separated to avoid confusion. Seeberger (Ref 118) also highlights the importance of a properly laid out instrument panel.

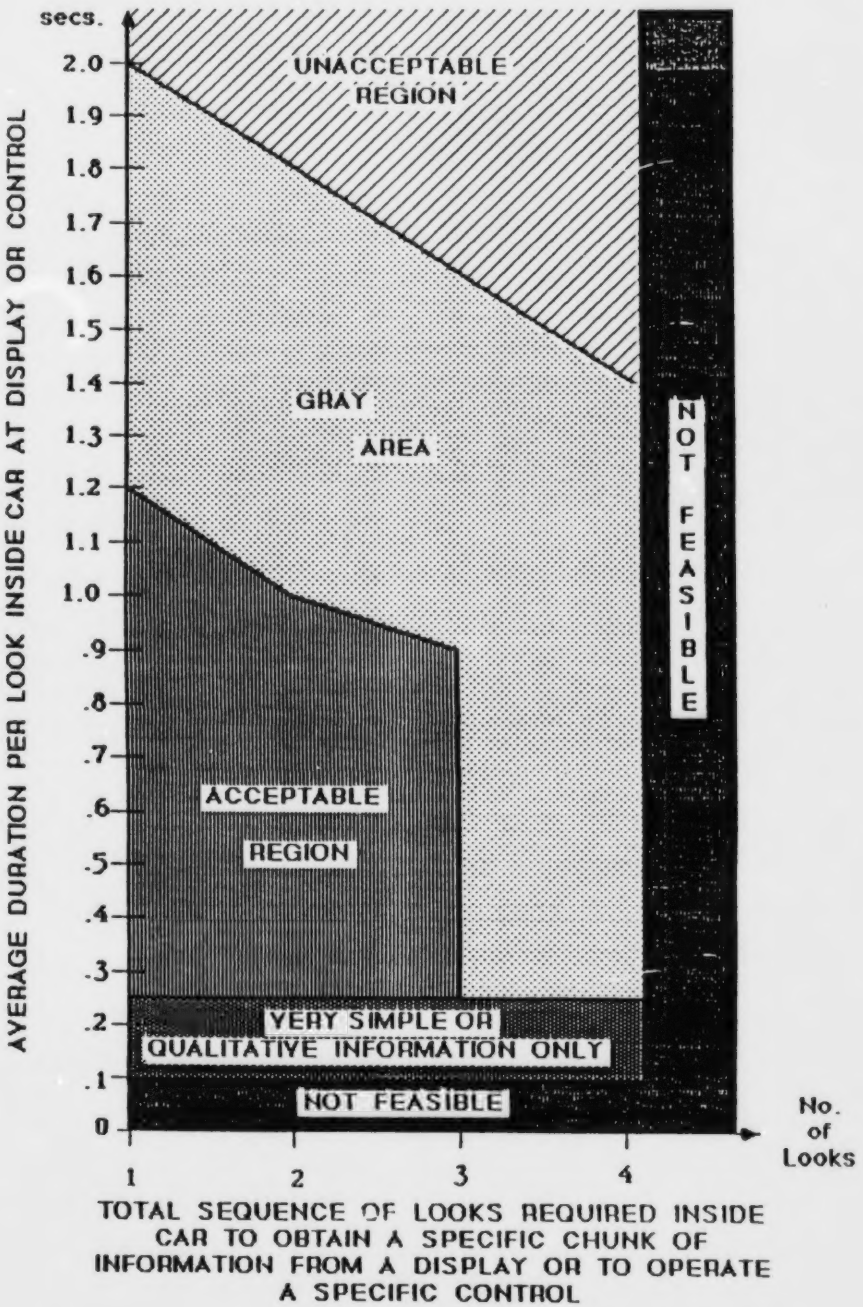
One possible design guide to be used when designing a visual display is presented in Exhibit 18. The graph is based upon the work of Senders et al (Ref 119), Zwahlen (1979 Tunnel Study) and Zwahlen (1985 RRPM Study). Note however that these values are for very undemanding driving situations only (tangent sections/very light traffic/90 km/h) and would have to be modified to consider more stressful driving situations (such as curve driving or heavy traffic).

There seems to be little or no research which has been performed to compare the advantages of one type of display technology over another. Although, the ANSI Standards for VDTs, which were still in draft form as of July 1986, could be utilized as minimum display performance requirements. The information that is available deals primarily with the evaluation of a CRT based display. Isensee (Ref 111) comments that when a CRT is placed in the periphery of the visual field of a person, flicker from the screen becomes much more apparent and annoying to the person. To combat this problem Isensee

EXHIBIT 18

POSSIBLE DESIGN GUIDE TO BE USED WHEN DESIGNING IN-VEHICLE DISPLAYS OR CONTROLS

- Tangent Sections of Roadway Driving & Very Light Traffic -
[55 MPH]



suggests that the video luminance should be reduced but the reduction should not be to such an extent that the legibility of the display is decreased.

Chao et al used the subjective scaling of subjects to evaluate some digital imagery which was displayed on a CRT (Ref 104). They were able to determine that the interpretability of the screen decreased as the signal to noise ratio decreased. They also found that a reduction in the interpretability was more distinct with increasing degradation of the screen. Simmonds (Ref 120) presents a block diagram which outlines major considerations in the design of automotive visual output devices (Appendix C.4). This diagram has been modified and expanded for this study, and is presented in Exhibit 19.

b) Man-Machine Output Interfaces - Auditory

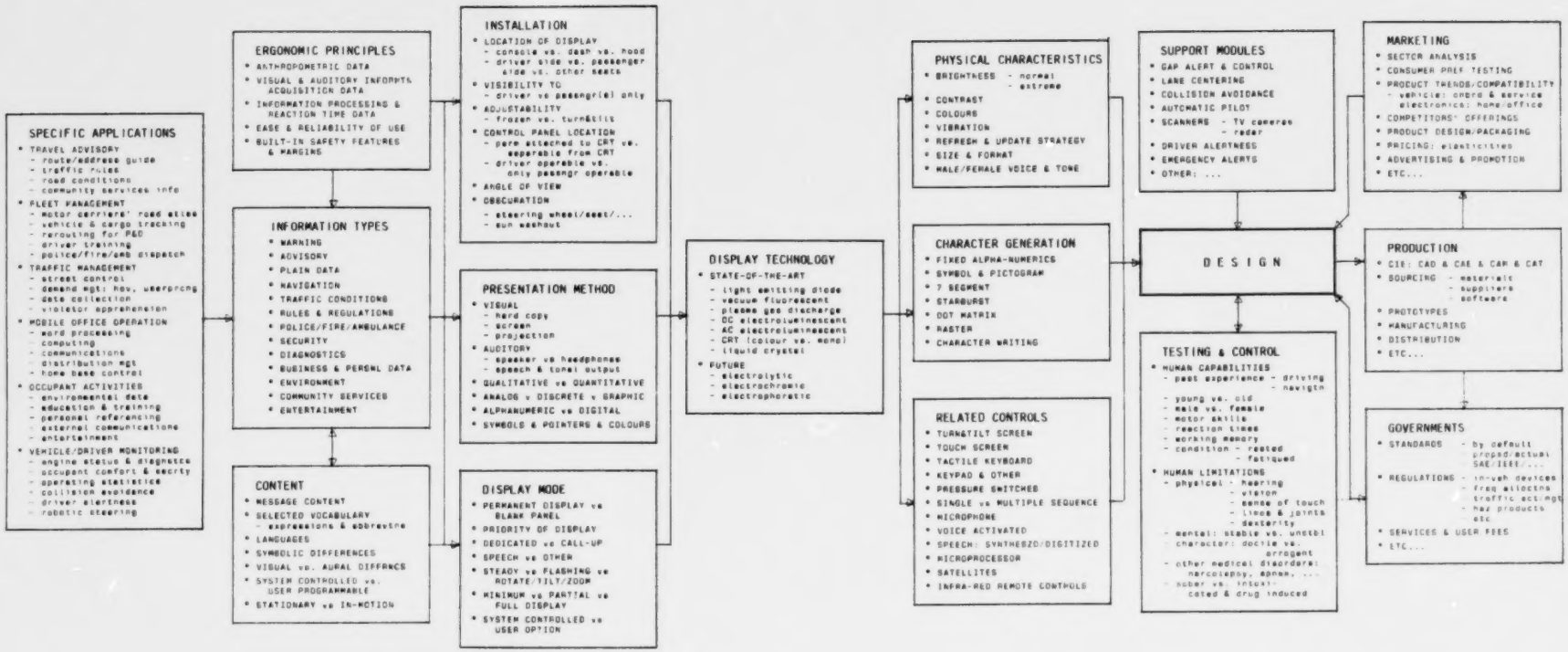
There are many instances where an auditory information presentation is desirable for use in an automobile based on the guidelines of Simmonds and Galer (Ref 121). McCormick and Sanders (Ref 114) give more specific guidelines for warning and alarm signals, such as:

- use frequencies between 200-5000 Hz and preferably between 200-3000 Hz
- use frequencies below 100 Hz when signals have to travel long distances
- use frequencies below 500 Hz when signals have to bend around corners
- use a modulated signal of 1 to 8 beeps per second
- use signals with frequencies different from those that dominate the background noise.

Signals should be discriminable from one another and where feasible use a separate communication system. Simmonds and Galer agree with the recommendations of McCormick and Sanders but add that overloading of the auditory channels can lead to irritation and stress and should be avoided. Hakkinen and Williges (Ref 109) assert that an alerting cue should also be provided before a message is sent in order to minimize the probability of the message being missed.

EXHIBIT 19

ELECTRONIC DISPLAY DESIGN GUIDE



MOBILE INFORMATION SYSTEMS IMPACT STUDY
Jouko A Parviainen & Associates, Final Report, 31 Aug 88

Many human factors experts feel that speech can be used to relay messages since it is the most natural communication channel used by man. Edman states that when using a speech presentation mode, digital or prerecorded speech is best (Ref 105). Edman also explains that speech should be used:

1) when communication flexibility is necessary
2) when it is necessary to determine source of message
3) when a stressful situation might cause the listener to forget the meaning of a coded signal
4) when a coded signal can not give ample instruction
5) when ambient noises obviate the use of tonal signals
6) when tonal possibilities have been exhausted
7) for continuous information.

Simmonds and Galer suggest that 250 words per minute is the maximum rate of transmission. They also give two warnings:

1) industrially induced hearing loss occurs in the speech bands and could have serious implications for speech communication, and
2) auditory messages should not be used to solely present important information since there is a possibility that the driver of a vehicle is either partially or fully deaf.

3.4.2 Man-Machine Input Interfaces

Several of the new display systems are actually also used for controlling some vehicle function - therefore, the placement of such displays critically effects their usefulness. Proper placement cannot be achieved without correct anthropometric data. The placement of controls should be based on the data to cover from the 95th percentile males to the 5th percentile females.

The type of controlling device also effects the driver's ability to use the control. Rather than using conventional knobs and levers, several manufacturers are considering the use of "touch screens". Albert found that the touch screen was a very fast method of controlling a screen cursor when compared to other devices - however, he also determined that the touch screen was very inaccurate since the users view is obstructed

during the screen touching. Another draw back to the use of touch screens is that many times a user may be wearing gloves during the operation and provisions must be made to handle this situation. Also, with a touch screen, the user is required to look at the screen in order to use it whereas with conventional controls the operator can "feel" the control and therefore need not look at it. Thus, the "feel" of the knobs could actually be considered a tactual information output interface.(* Further, the dynamics involved in trying to perform a control sequence on the touch screen, when the vehicle is in motion in such a way that the automobile is bouncing and shaking, may make the controlling task too difficult for some drivers.

Zwahlen and DeBald undertook a study using a simulated CRT touch screen mounted in an automobile (Ref 132). The screen was modeled after 1986 Buick Riviera's "Graphic Control Center" display. Subjects were asked to perform typical controlling functions using the simulated touch screen while driving 40 MPH (64 km/h) down an unused airport runway under ideal driving conditions. The results of the study showed that a driver has probabilities of 2.3% and 12.9% of laterally deviating out of the lane for lane widths of 12 feet and 10 feet (3.66m & 3.05m) respectively.

Zwahlen and DeBald recommend that in the development of displays, tasks requiring subsequent control inputs by the user should be broken up and presented to the user as distinctly different operations; and/or the number of touches required by the user should be reduced; and/or the touch areas of the CRT touch panel controls should be enlarged, in order to allow intermittent eye fixations on the road scene ahead and intermediate vehicle path corrections during the completion of the task. They also feel that at the present, the touch panel controls require a reading-processing-acting time which is far too great in terms of the measured lateral lane posi-

*) Obviously the surface of a touch screen could incorporate (a few) different textures to make it easier for the driver to know (ie. feel) the command area from which he is about to release his finger. These different texture surfaces would then simulate, at least to some extent, set of function keys or regular switches.

tion standard deviation values at the end of operation times for relatively simple tasks (eg: setting the climate controls or turning on and finding a desired frequency on a radio).

An additional method of inputting control information which has been discussed in some circles is the use of speech recognition systems. These types of systems would eliminate the need for the driver to divert his/her visual attention from the road and would eliminate the need for the driver to remove his or her hand from the steering wheel in order to manipulate a control, thus the safety of the system would be enhanced. These types of interfaces are however still in the development stage since the recognition of voice input is a very difficult task (in an automotive environment) and thus far has only limited reliability. Also, the designer must be careful not to implement these systems so that they solely control functions since it can not be assumed that the driver is capable of speech or that the driver speaks and/or understands the language which is being used to present the message. This may be true of any driver under extremely stressful situations.

3.4.3 Concluding Remarks

The use of sophisticated in-vehicle displays will continue to escalate in the future. However, until suitable standards and regulations have been developed, it is recommended that the use of the new displays should be approached with extreme caution; in some specific cases and for some specific purposes should possibly be abandoned altogether. While there might exist several benefits from the use of some sophisticated displays (map displays: optimal route guidance, fuel and time savings, etc.), the trade-offs with regard to safety issues must be done with caution and must be based upon solid experimental data. The safety of the driver, passengers, other drivers and pedestrians should not be compromised in any way. Humans must not be overloaded to the point where they cannot safely perform the primary task which is driving.

3.5 USER INTERFACE APPROACHES

As described above, the approach to the interface between an on-board navigation system and the vehicle operator and/or passenger must take into account ergonomics and safety considerations as well as functional requirements. Most systems proposed or developed to date use detailed map displays or some combination of symbolic graphics, alphanumeric messages and audio signals. Insights on the driver interface issue may be gained by summarizing approaches that have been tried or proposed.

3.5.1 United States

Some of the most serious research on driver interfaces was done in connection with the ERGS project of the late 1960's (Ref 20). The ERGS vehicle unit back-illuminated various combinations of arrows and words on a guidance panel. Tests were also conducted with "heads up" displays which projected simple combinations of arrows and words on the windshield so that the driver did not have to remove his eyes from the road (Ref 51).

In the early 1970s, ARCS - an automatic route control system developed for operation over programmed newspaper routes - used prerecorded audio route guidance instructions during extensive operational tests (Ref 13). This approach worked well, but tape recorded audio instructions were awkward to prepare and control, and synthesized speech was not yet available. Therefore, an improved version used a plasma display panel to give route guidance in the form of shaped arrows along with street names, etc. (Ref 40). Subsequent research reported by Streeter (Ref 52) established that drivers who listened to directions drove to destinations in fewer miles, less time, and with about 70 percent fewer errors than drivers using customized route maps.

The next generation of systems development in the United States used CRT displays for the driver interface. These included satellite-based navigation systems demonstrated by

Ford (Ref 31), General Motors (Ref 29), and Chrysler (Ref 32), all of which displayed detailed map images. Etak Navigator, the only advanced automotive navigation system actually on the market in the U.S., carries the trend a step further by displaying a map that rotates to match vehicle heading (Ref 14). Lettering also rotates to make the text continually readable to the user.

3.5.2 Europe

European automobile navigation system designs seldom use elaborate visual displays for the driver interface. One exception was the first version of the Philips CARIN system (Ref 41) which includes a colour CRT map display for showing vehicle location relative to the surroundings. CARIN includes synthetic voice for conveying instructions to the driver when operating in the route guidance mode. Another exception is the Bosch-Blaupunkt licensed version of Etak navigation unit.

The earliest example of a route guidance system incorporating automatic route generation using on-board digital maps was "Micropilot" developed in England in 1981 (Ref 53). This system used an audio interface in the form of a digitized voice - not speech synthesis - with a vocabulary of 26 words.

West German designs invariably use simplified visual displays, sometimes in combination with audio messages, for conveying route instructions to the driver. Virtually all West German systems to date use some combination of short visual messages, symbolic graphics and/or voice.

One example is the route guidance system described by Haeussermann (Ref 54). When on highway networks, this system uses a 2-line LCD display with 16 characters per line to give the next route point and remaining distance. When on city streets, an alternate LCD display with a pointer indicates the direction of the destination, and shows numerals to indicate the remaining distance.

The first generation EVA system developed by Bosch-Blaupunkt also uses simplified graphics to convey route instructions (Ref 43). The original prototype includes differential odo-

meter, map data base with map matching, and route search software to generate explicit route guidance instructions. The main display includes a vertical LCD panel for graphics and a small horizontal LCD strip for character display. Voice capability is included, and is used to confirm destination entries. Turns at complicated intersections, lane changes, etc are specified to the driver in the form of simplified diagrams which show lane boundaries and use arrows to indicate the path to be taken.

Bosch-Blaupunkt also provides the interface equipment for the ALI-SCOUT system, a joint project of the West German Government, Siemens, Volkswagen, Blaupunkt and others. ALI-SCOUT is also a route guidance system, but rather than being autonomous, it depends upon the reception of area road network data and recommended route data broadcast from strategically located IR beacons (Ref 24). Driving directions are presented much the same way as in EVA, but with an additional feature similar to the "Wolfsburg wave" (Ref 53a). The Wolfsburg wave is essentially a bar graph that, in this application, gives a "count down" to the exact point where the vehicle is to turn, thus clearly delineating among closely spaced turns.

Destination input, as well as system control, for ALI-SCOUT (which will be subjected to large scale user tests in West Berlin starting 1988) is via a hand held wireless remote control unit with shift keys for alphanumeric information. Thus initializing the system for a trip will be much like remotely programming a VCR, and may be done by anyone in the automobile (an important safety consideration).

3.5.3 Japan

Current driver interface approaches for Japanese automobile navigation systems seem to align more with those of the U.S. than with Europe. Japan's first major step toward route guidance was the CACS (Comprehensive Automobile Traffic Control System) project (Ref 22) of the 1970s which was patterned after the U.S. ERGS (Electronic Route Guidance System) project of the late 1960s (Ref 20). Like ERGS, CACS used simple com-

binations of direction indicators and descriptors to indicate routes to be taken.

Autonomous navigation systems started appearing in Japan in the early 1980s. The Nissan Driver Guide System (Ref 54a) displayed information in a simplified graphical form "in order to make the bearings and distance to the destination easily viewable while driving." Directional arrows showed the direction to the destination, and a bar graph indicated the fractional distance remaining.

Appearing about the same time was the Honda "Electro Gyro-Cator" navigation system (Ref 55) which used a CRT display to show a plot of the vehicle's path. Location could be established by using a transparent map overlay.

Subsequent systems shown in Japan incorporate colour CRT map displays. These include systems displayed by several automobile manufacturers at the October 1985 Tokyo Auto Show (Ref 21). Another example of recent directions is a Loran-based Nissan delivery truck system which also uses a colour CRT map display (Ref 66).

New integrated systems approach currently under joint development by Japanese industry and government groups potentially includes an on-board computer, CRT display, compact disk with road network data, dead reckoning sensors, roadside electronic signposts for location confirmation as equipped cars pass within range, and map matching to augment dead reckoning between signposts (Ref 21).

4. MARKET PERSPECTIVE

4.1 APPLICATION AREAS

4.1.1 Applications & Benefits

The primary functions of conventional vehicle 'navigation' systems are positioning, navigation and route guidance, ie. the systems are usually designed to:

- identify the vehicle's (map) position, thereby making possible basic rudimentary navigation by the driver or passenger (or location monitoring by a dispatcher), and
- give (advance) advice on the best route to take to reach the original, or a newly established, destination.

However, fully developed mobile information systems can be expected to provide a broad range of capabilities in the future, making them adaptable to many different circumstances. Six major possible application areas can be identified; the names of these areas also, in effect, describe the purpose(s) for which mobile information system may be used:

* travel advisory
* fleet management
* traffic management
* mobile office
* occupant activities
* vehicle/driver monitoring and control.

The primary expected benefits (or goals) of future mobile positioning/navigation/information systems - and the means of achieving these benefits (with the help of the systems) - are summarized in point form for each application area in Exhibit 20. No distinction is made as far as the actual system user is concerned; all user groups may be equally concerned about 'optimizing' their routes - albeit probably based on different priorities or preferences (eg. shortest vs most scenic).

EXHIBIT 20

PRIMARY BENEFITS OF MOBILE INFORMATION SYSTEMS IN THEIR MAJOR APPLICATION AREAS

APPLICATION AREA	PRIMARY BENEFIT	MEANS OF ACHIEVING
TRAVEL ADVISORY	Minimize costs	optimize route selection & travel timing minimize number of lost motorists
	Increase overall efficiency	provide marketing & community information
	Maximize enjoyment	provide road side/attractions information provide on-board entertainment & education.
FLEET MGT	Maximize efficiency	optimize P&D path & load consolidation
	Improve level of service	monitor vehicle and shipment location
	Increase equipment utiliztn	predict vehicle and driver availability
	Increase security	provide convoy mgt & automatic tracking
	Provide mgt information	accumulate operating statistics
	Increase public transportation productivity	provide information on park&ride facilities provide information on departures/arrivals.
TRAFFIC MANAGEMENT	Utilize corridor capacities more fully	support fwy/art traffic management systems support preferential treatment of HOVs
	Temper growth in new traffic	support demand management measures: access control, user pricing, etc
	Increase safety	support flow control & incident management improve law enforcement.
MOBILE OFFICE	Extend office capability into the vehicle	provide customer and product lists provide paging & dialing & dictation process invoices, cargo slips, ...
OCCUPANT ACTIVITY	Increase enjoyment	reduce uncertainties related to travel provide access to a vast activity library
	Save money and time	take full advantage of competitive pricing on goods and services.
VEHICLE /DRIVER MONITORING	Increase road safety	diagnose likely (vehicle) failures early increase vision in all directions monitor driver condition & alert if reqd
	Reduce vehicle costs	support/teach good driving practices support preventive maintenance program.

4.1.2 Broader Goals

When mobile information systems are applied in these areas, they can also contribute to broader environmental and quality-of-life goals through the following means:

Goal	Means
increase environmental awareness	provide environmental information provide historical information
conserve resources	reduce air and noise pollution reduce material requirements reduce hazardous product spills help transition to livable cities
improve fairness	charge for use of facilities based on space taken and the time/duration of use
respond to special needs	make driving easier for disabled and aged decrease transportation stress for all speed up emergency detection/response
improve access to information	provide mobile on-line access to business, personal and societal data.

4.2 USER COMMUNITIES

Three distinctly different user communities, or primary markets, where mobile information systems are likely to be implemented, or their capabilities at least somehow utilized, can be identified:

DIRECT USERS — who install the devices in their company's or their own vehicles - for the purpose of obtaining advice to meet their travel needs, managing their fleet, operating a mobile office, providing activities for the vehicle occupant(s) and/or assisting in control of the vehicle

INDIRECT USERS — who use the information provided by those in-vehicle devices on the road which transmit on public frequencies or can be polled on demand - in order to collect data, assist in traffic management, control/limit access to certain areas, aid in cargo management, apply user pay, enforce rules of the road, etc

INTERMEDIARIES — who provide public and private information services by transmitting into vehicles which have units with reception capability (ie: information on community events/facilities, product marketing, etc).

These groups may be considered to include the following:

* public-at-large
  - meeting commuting, personal and family travel needs
  - accessing general/community information
  - providing in-vehicle activities
* private businesses
  - management/control of (vehicle born) operations: pick-up and delivery, business travel, ...
  - customer service (eg. tracking of shipments)
  - maintenance of company vehicles, in support of fleet management information system (FMIS)
* for-hire freight carriers
  - urban P&D and intercity transport, courier services
  - maintenance of company vehicles (in support of FMIS)
* freight terminals and warehouses
  - improved consolidation of shipments
  - optimization of P&D operations at dockside
* public and private passenger carriers
  - buses: intercity regular route and charter, school, scheduled and demand responsive (E&H) services
  - taxi & shared vehicle fleets
  - short and long term rental/leasing fleets
  - urban rail transit (for transmission of park&ride information to car commuters)
  - maintenance of company vehicles (in support of FMIS)
* government departments/ministries and agencies (federal, provincial and municipal)
  - provision of services to the public, which require:
    - the use of (gvt) vehicles for access or delivery
    - transmission of information to all or targeted vehicles on the road (for community marketing, etc)
  - management and delivery of agencies' internal programs (eg: maintenance of road system, resources mapping, refuse collection & recycling, utilities, ...)
  - national defence (preparedness training, maneuvers)
  - maintenance of agencies' own fleets (support of FMIS)
* public and private providers of emergency/security services
  - police, fire, ambulance, guard patrols, etc

* automobile oriented service agencies and associations
  - automotive service centres
  - automobile users' associations (eg CAA)
* tourism and leisure industry
  - lodging industry: hotels, motels, campsites
  - activity centres, entertainment complexes, ...
  - tourism bureaus & chambers of commerce
* electronic service bureaus
  - E-mail, electronic data interchange (EDI)
  - on-line data bases, videotex, paging, etc
* others - driver training schools
  - ...

A preliminary coding system for establishing a user/supplier/regulator contact data base is presented in Appendix D. These codes have been used to tentatively categorize associations which, in Canada, would represent the interests of likely (direct/indirect/intermediary) users of mobile information systems. A preliminary associations list was developed; this will be useful as a starting point for undertaking more extensive surveys and interviews into the needs and requirements of these user groups.

No reference lists have been prepared for specific user groups, such as trucking companies, intercity passenger carriers, etc. The membership rosters of their respective associations and other publicly accessible directories provide ready reference for anybody wishing to undertake a survey of such user groups.

4.3 SYSTEM FUNCTIONS

4.3.1 Functions & Features

The above user groups can be expected, in due course, to apply mobile information systems in many innovative ways. This may well parallel the quick expansion of uses to which home and office micro-computers have been applied. Indeed, many of those innovations are readily transferrable on-board vehicles as soon as mobile systems - containing a microprocessor, some

data storage device, an input/output device and a communication module - are installed.

The primary functions and representative features/content that might emerge within each of the application areas are presented as follows: travel advisory (Exhibit 21), fleet management (Exhibit 22), traffic management (Exhibit 23), mobile office (Exhibit 24), occupant activities (Exhibit 25) and vehicle/driver monitoring and control (Exhibit 26).

It should be noted that while no system currently on the market or in the planning stage offers such a range of capabilities, all features are readily (albeit not necessarily cheaply) implementable with state-of-the-art electronics hardware and software technology - as long as a basic Geographic Information System is in place and all required databases and on-line support systems are implemented/tied into the mobile system network. Therefore - in a strictly technical feasibility sense - the travel advisory features 'wishlist', for example, is a realistic one. In the same limited sense, so are the lists for the other application areas.

An overall functional block diagram for future mobile positioning/navigation/information systems is presented in Exhibit 27.

EXHIBIT 21

TRAVEL ADVISORY APPLICATIONS

Function	Feature / Content
ROAD MAP	* general road atlas - road network layout - major attractions (user-selectable categrs) * street name & route no. & section length * facility type (limited access, toll, ...) & terrain (grade) * addresses: odd&even numbers for upcoming block + pin-point loctn * ...
TRAFFIC RULES	* speed limits/parking&turn restrctns/HOV ramps&lanes (see TrfMgt) * weight limits / designated routes (trucks & dangerous goods) /.. * snow clearance (days & sides) / special event conditions * ...
ROUTE GUIDANCE	* CBD circulation maps (one-way pairs, parking, ...) * downtown exit guide: find open fwy entry ramps from anywhere * en-route reception of InfoRoad etc + suggested route updates * trip computer (with planned vs actual comparisons) * traffic responsive, dynamic advisory: reception, storage, display of traffic control centre signals (see: Trfc Mgt): - HAR/AHAR announcements & ramp control (on/off) - changeable sign messages (actual signs & in-betw locn messgs) * ...
EMERGENCY RESPONSE	* emergency broadcasts, to capture&store radio+TV alerts (chemical spills, nuclear disasters, ...) * search & rescue missions in natural and man-made disasters (guidance to & around site) * emergency CB: transmsn of medical/mechanicl/crime distress calls * ...
PUBLIC SERVICE MESSAGES	* road conditions - weather & traffic & incidents - construction & maint. closures - garbage disposal emergency regulations * general weather alerts: storms, floods, ... * special events: content & location & times & parking * transit - route maps & next arrival based on bus line/stop code - park&ride: location, space available, charges * pass&freight terminals - access & circulation & parking - carrier location & dep/arrvls * customs information: rules, line-ups, ... * mobile billboard reception: drunk driving prevention prg, ... * ...
ROAD SIDE & COMMUNITY SERVICES INFORMATION	* adjacent land use & block face information * fuels & repair service / food&lodgn / rest&picnic sites / prks * electronic bulletin board: community events & ... * yellow pages by store type & product category (eg. 'telefind') * distributors' lists of retailers for certain products * subject registers: Thomas Register & Thomcat (=company catlgs) * videotex: mobile teleguide kiosk (eg. France's 'Minitel') * shopping centre profiles: layout & store locations by type * in-veh browsing of electronic stores: viewing of 'liquid crystal price panels'for daily specials & * realty 'radio': property data sheet & floor plans * ...

EXHIBIT 22

FLEET MANAGEMENT APPLICATIONS

Function	Feature / Content
VEHICLE & CARGO POSITION TRACKING	* display of vehicle & shipment location at control centre (postal&cour services' admin vehcls/tractr trlrs/cargo vans/...) * dispatching & rerouting (P&D changes): freight & taxi & emergncy * schedule/route/safety adherance -> central dispatch intervention * load factor monitoring & opertn of destination/pass info panels * emergency vehcls control: police & fire & ambulnce & public utils (reduce response time + increase officer safety) * ...
ROUTE GUIDANCE	* motor carriers' road atlas & intercity routing guides (tolls,.) * industrial site access maps (c/w advance block signals) * maximum dimensions and weights: roads, bridges, tunnels * municipal regulations: truck routes & operating days/hours * heavy specialized carriers' routes & hazardous cargo routes * road geometrics alerts: recommended max ramp speeds, ... * weather alerts: wind, icing of road surface, snow squals, ... * traffic conditions: reasons for delay (incident reports, ...) * pre-departure/pre-entry advisory: anticipated clearance time * ...
VEHICLE & CARGO & OCCUPANT SECURITY	* automated emergency response system (AERS) (when parked, ...) * distress calls - unruly passengers / heist / ... - help request for disabled vehicles / ... * convoy management: commercial & private vehicles * electronic guard dog * ...
DRIVER TRAINING	* video & audio instructions * feedback - driving performance: L/100km & gaps & handling - rules of the road (from map data base/emitting signs * ...
LAW ENFORCEMENT	* electronic mug book: picture&description of dangerous offenders * lost child/adult: picture & description * electronic 'pin map' for VICARS (visual integrated crime analysis reporting system) * patrol routes/schedules/sp. targets: display + random changes * search perimeter (to be sealed off) & route-by-route coverage * electronic house arrest (ankle bracelet extended to vehicle) * locating (=recovery) of stolen vehicles & cargo * ...
AMBULANCE & FIRE	* dangerous chemicals referral system by Class & unidentified * emergency contacts on building layout & content (transmission of floor plans & equipment locations) * emergency contacts on municipal utilities locations * incident management teams: command post communications * ...

EXHIBIT 23

TRAFFIC MANAGEMENT APPLICATIONS

Function	Feature / Content
STREET CONTROL	* one way streets & reversible streets/lanes & turn restrctns * parking restrictions & snow clearance routes/schedules * loading/unloading rules & ... * high occupancy vehicle designations * violator assembly sites (directions from freeway, etc) * emergency clearance: toxic spills / fires / chase / storms /... * event management * transmission of electronic destination etc signs' content * parking: display of prepurchased electronic tokens at meter * ...
FREEWAY MANAGEMENT	* incident detn/verifctn/response & surveillance/control measures * transmission of: - corridor conditions reports (for requested O&D) - ramp & lane closures - alternative routes & advisory speeds - pre-trip advisory - avr & hour-specific O&D travel times - suggested alternative departure times
VEHICLE ACCESS	* road use pricing by peak/off-peak & by vehicle type + homebase * access control (via vehicle/driver ID transmission) * parking availability & rates by type (all vhs, HOVs only, ...) * designated routes: trucks & dangerous goods & snow & garbage col * ...
ENFORCEMENT	* transmission of - radar & airplane detected excess speed (& other maneuvers) - electro-optically detected tailgating - axle load & route & hour violations - HOV facilities use by SOVs - usual fine/demerit implications of violation spotted - pull over & stop command * accident reconstruction, ie. short term memory (black box) on: - driving maneuvers & speed - lane positioning & ... * enforcement & apprehension of - violator vehicles (c/w electronic record for courts) - violated vehicles * accumulation of - special merit points - demerit/violation points * ...
TRAFFIC DATA COLLECTION	* trip frequency / O&D / chaining / occupancy / vehicle type / * alternative route selection (vs. advisory sign message used) * comparative travel times (by time of day & by alt. route) * road & street inventory data & updates * road surface scanning data (from laser cameras) * ...

EXHIBIT 24

MOBILE OFFICE APPLICATIONS

Function	Feature / Content
WORD PROCESSING & COMPUTING	* commuter work stations (in car/van pools & subscription buses) * word processing & memo pads * study periods: seminar tapes etc * calculator: 4-function, business, engineering, scientific * compressed register by product category: Thomas Reg & Thomcat * manufacturers lists of wholesalers & distributors * industrial sites ref cataloque: boundaries & leases & vacancies * ...
COMMUNICATIONS	* paging & messages transmission: company and personal * automatic dialing (customer list vs. diary order&location) * courier status (eg. from FedExp's COSMOSS tracking system) * facsimile transmission/reception (& photophone still pictures) * electronic bulletins: infloglobe, stock quotes (seld portfolio) * EDI (electronic data interchange) * telemarketing - comprehensive client list (including personal data, ..) - customer/dealer/supplier locator: map location & postal code - daily diary & orders & follow-up call requests - electronic scratch pad (retrievable notes during phone calls) * ...
FREIGHT	* electronic cargo routing slips (+ wand for loading&unloading) * freight - tariffs & rates & regulations - haz cargo: data base & emergency contacts/procedures - in-vehicle stock control * terminals: locatns & hours & personnel & line-up # & wait times * custom operations - hours & regulatns & duties & locn of in-land clearance houses - CSS (customs commercial system): tariff classification - CADEX (customs automated data exch prg): entry data to customs * motor carrier accident report - automatic entries (tach data) - preparation (manual input) * travel exp recording: km/time/fuel allocn & motel invoices * accounting: daily transactions * ...
HOME BASE CONTROL	* 'smart home' - appliances (pre-arrival on) / security / ... - answering machine: messages review & reset - ... * 'butler-in-the-box' voice command system * ...

EXHIBIT 25

OCCUPANT ACTIVITY APPLICATIONS

Function	Feature / Content
ENVIRONMENT DATA	* adjacent environment: geography & fauna & ... * '4X6 cards' & charts on basic sciences * environmental protection - data bank on toxic discharges & rain - fundamentals on earth's egosystems - regulations & 'acceptable' limits * recreational & cultural data banks * ...
EDUCATION & TRAINING	* standard & inter-active audio/video courses * encyclopedia & yearbooks & personal interest sheets * science summaries * compressed summaries (of publications) for executives, etc * language training & music studies & ... * calculator functions: 4-function, scientific, engineering, ... * ...
PERSONAL REFERENCES	* family & friends data base: names, birthdays, addresses, phones, * health care - health & diet information - transmission of heart beat pattern - reception of analysis results & advice - en-route/in-vehicle analysis * household finances: purchases record, due dates (automtc flags) * local phone book & community contacts * activities list - todays musts (user selectable time buffers) - household tasks-in-a-cookie-jar * ...
ENTERTAINMENT	* games: against computer & amongst occupants * music - CD player control (tracks pre-selection by each indivl) - radio stations scannig - composing & play-back (casette recording) * veh<->veh communictns: messages/driving 'instructions'/flirting * ...
EXTERNAL COMMUNICATIONS	* inter-active responses with external systems - particptn in computerized auctions: retail value & highest bid - en-route/ pre-arrival - motel bookings (room type & rate & durtn) - motel confirmations & cancellations - fast food group orders (express pick-up) - telemarketing: product review & response (smart card) - in-vehicle video shopping (~ 'CanValNet' cable shopping) - libraries' lists of ref material (eg. 'home access') - remote access to ATM networks (electronic banking) * ridesharing pick-up/drop-off modifications (veh<->house transmn) * electronic hitch-hiking - h-hker and driver registration confirmation - destination sought * monitoring of electronic babysitter signal * ...

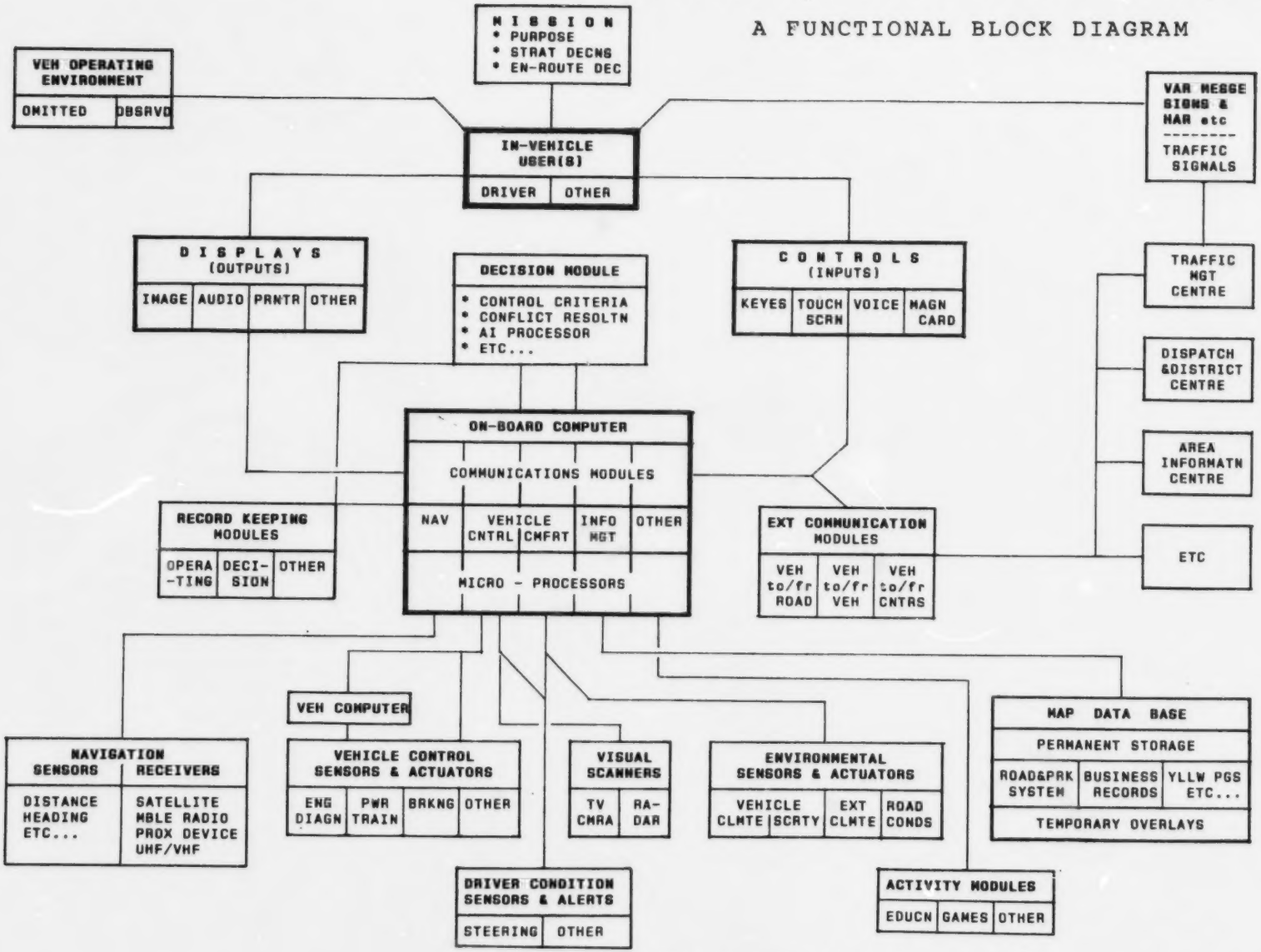
EXHIBIT 26

VEHICLE/DRIVER MONITORING AND CONTROL APPLICATIONS

Function	Feature / Content
VEHICLE/ DRIVER MONITORING	* status of vehicle systems – diagnostic displays – anticipated failure alert – response-to-failure tips * driver alertness monitoring (eg number of steering corrections) and alert ('snooze alert') & automatic ltd vehicle response * on-board physiological monitoring (eg. military) * vehicle maintenance – tips (eg. jump start steps to protect electronics) – customized work order processing for prev maint. – warranty expiration alerts – calls: tow vehicle availability and rates * operations statistics for each driver: h & km & L of fuel & ... * manner-of-use record for each driver (with exception alerts): speeds (actual & compared to limits) & idling & abrupt handling * ...
VEHICLE CONTROL	* collision avoidance systems – minimum gap alert (Rashid VRSS) – weather & surface friction alert – suggested maximum speeds * rear view display & ultrasonic obstacle warning for backing up * night time infrared forward imaging system (obstruction alert) * perimeter vision/scanning (for extra long & wide loads) * specialized controls/features for handicapped and/or elderly * anti-theft device: starting by key code/voice print/smart card automatic transmission of tracking signal disabling of essential controls * comfort – radio station/tape/CD selection (individualized) – individualized positioning of: seat / temp / windows / * ...
AUTOMATED CHAUFFEURING	* automatic highways (median lane control) – steering function – accelerator/brake functions * agriculture & mining & manufacturing (robotic steering): computer controlled and steered combines, forklifts, etc * man-made and natural disasters response: spills & fires & ... * military operations (autonomous land vehicles): surveillance / reconnaissance / advance columns / mine field clearance/ ... * ...

FUTURE MOBILE INFORMATION SYSTEMS

A FUNCTIONAL BLOCK DIAGRAM



MOBILE INFORMATION SYSTEMS IMPACT STUDY

Jouko A Parviainen / Parviainen & Associates

4.3.2 Preferences of Some User Communities

In order to gauge the current knowledge, the expectations and future intentions of the potential user communities, a fairly extensive market survey would need to be undertaken. The emphasis in this task of the study was to design and test an interview guide that would provide a useful starting point for developing a large scale interview type survey.

Even though it was recognized that very few would have prior knowledge of mobile navigation/information systems, or about the current 'rates of installation' in their industries, the questions were designed to be useful for future tracking of implementation levels.

The test survey consisted of a dozen face-to-face and telephone interviews; the number was considered just sufficient for testing and modifying the interview guide (Appendix H) and for getting some feel of the different market sector preferences.

Due to the very small sample, no statistical summaries or analysis are attempted. However, a short recollection of the main directions and themes that appeared to emerge from the discussions with representatives of the user groups, is presented in the following (the headings refer to main topics in the interview guide). It should again be noted how very few interviews were undertaken; therefore, these 'findings' can only present a limited and incomplete view even at this summary level.

Familiarity With The Systems

In general, there was little prior knowledge (except by the trucking industry and emergency agencies) - however, there was always quick appreciation of the main capabilities (of positioning, navigation and route guidance) of the mobile systems and their possible usefulness to the user community (this will ease some of the burden on those marketing the systems in the future). Many expressed surprise about the range of possible features that these system might ultimately offer.

Current Installation Base

Practically none within the user communities surveyed. The focus, in what experimental installations there are, seems to be on AVL, with the vehicle location continually monitored at the dispatch centre; transmission of the location to the vehicle itself takes place on an as-needed basis only.

Desirable Functions

What functions/features were considered high, medium or low priority, or not relevant at all, depended heavily on the user community (one representative rating is presented in Appendix H/p.3). Four capabilities, however, were rather uniformly requested; the users would like to:

- know the vehicle's map position - at least at a dispatch or operations centre (if there is one), or else inside the vehicle; position relative to requested destination (eg. given as turn instructions) would suffice for many, who did not consider an actual map display that critical
- record vehicle use and manner-of-driving statistics for each trip, or separately, for preset categories of trips (also separately for each driver, where required)
- record en-route events (ie. replace a manual business log, or a personal note pad) and/or provide semi-automated data gathering (with automatic reference to vehicle position, time of day, etc)
- display items from a company and/or personal 'base inventory' on demand; the content and structure (or expected manner of use) of such data bases is quite peculiar to each user group.

Characteristics

'Competitive' price, and particularly all-inclusive life-cycle cost, was rated as the most important characteristic; however, speculation on what association members or the users would be prepared to pay varied widely depending on needs. An important factor was whether the user had already come to accept the need to invest in some equipment for similar purposes (eg. tachograph to control drivers and protect against insurance claims). The acceptable price range varied from $700 to $3000 (but then the feature expectations were also varied, albeit not exactly correspondingly).

To actually obtain a perspective on the "acceptable price/expected performance" ratio, will require proper market studies and sufficient size samples (using pre-specified alternative core packages and prices, available options, etc).

Functionality, primarily meaning the (utmost) ease in day-to-day use, was also rated highly; this was considered more important than how easy it might be initially learn to use the unit (even though these characteristics are quite parallel).

Input/output interfaces: for many users, simple function keys for input and a two- or three-line message for output appeared adequate (many would prefer a keyboard and a CRT screen for map display). For some groups, a remote 'wand', or an infrared 'extension cord' would be of great value (eg. for couriers handling packages at the back of the vehicle, emergency personnel being temporarily separated from their vehicles).

Required Performance

Position accuracy expected of these systems was perhaps one order of magnitude less than initially thought. Except for couriers, taxis and emergency/security services - who would like to obtain their vehicle position within a few metres (to be assured of correct city street and block, and clear freeway/arterial separation) - most would consider a 6-9 block area, or sometimes 0.5-1.0 km, sufficiently accurate. For mapping agencies, good position accuracy - ranging from 10cm to 1mm - was considered the primary requirement for a unit operable outside the vehicle.

Operational availability was not considered critical by most (after all, most have survived without any similar equipment until now) - at least not as far as positioning, navigation, route guidance, and many add-on features were concerned. However, there would be almost no tolerance for failures/interruptions on monitoring the manner of vehicle handling (as per current tachographs), or recording driver hours (and anything else required by regulations); and obviously zero failure tolerance on features related to actual vehicle control.

Curiously, while there was tolerance to possible electronics or system failures as such, the expectations - as far as **en-**

vironmental robustness are concerned - were very high. The design and testing are expected to be towards 'industrial' units, with long term parts&labour warranties, not for flimsy consumer gadgets.

Portability: the contrast on the desirability of the primary components being removable from the vehicle (so that the unit would remain operational for most of its features) was obvious. It was either considered highly undesirable (units would be subject to mishandling or theft), or essential (for home, office, commuter train, boat&cottage, etc use) to justify the likely total purchase plus upkeep cost.

Barriers & Needs

Barriers, most often quoted, were:

- price (assumed to be initially too high, due to lack of competition)
- lack of overall features, as well as individualized software that would make the systems really useful for a specific community
- unfamiliarity and management rigidity, somehow synergistically preventing staff access to learn about the systems or see them in operation and/or experiment with them within own fleets.

The response to the question on **future needs**, was perhaps the most uniform - all user communities, including those already experimenting with the first rudimentary devices, would evidently greatly benefit from:

- a major Canadian joint conference of direct/indirect/intermediary users, of suppliers of equipment, related components, software and data bases, and of regulators and others who would affect future standards and use (VNIS '89, or Vehicle Navigation & Information Systems Conference, has been subsequently announced: 12-14 Sept 89 in Toronto)
- state-of-the-art brochure or newsletter that would be updated periodically - containing (neutral) summaries of hardware and software available on the market or under actual development (ie. at least in prototype testing phase), Canadian supplier reference lists, topical discussions on current and future trends, descriptions of particularly innovative applications, and of directions in licensing and regulation.

Within the 'Wide Area Vehicle Monitoring System Project' (Ref 77), a survey of 97 for-hire carriers in Ontario was carried out; thirty three responded. Albeit small, this survey well illustrates the preferences and needs of one major user community - the for-hire carriers. (Limited number of copies of this report are available from the Ministry of Transportation of Ontario).

4.4 CANADIAN SUPPLIERS

The current and potential suppliers of mobile information systems could be broadly categorized as follows:

* suppliers of on-board equipment - designers, developers and manufacturers of hardware and system software (Section 2.3):
  - navigation and other sensors, processors and actuators
  - micro-computers, high speed graphics processors
  - data storage devices
  - input devices (switches, keyboards, wands, touch screens, ..)
  - output devices (screens, audio, printer, ...)
  - transmission elements: modems, antennas, beacons, etc
* suppliers of data packs - consolidators and suppliers of map (GIS) data bases stored (on CD-ROMs, etc) on-board vehicles plus providers of map overlays and other data files intended for transmission to vehicles on the road
* developers and suppliers of applications software (see Section 2.3.3/p.46-47)
* installers of equipment - vehicle manufacturers installing their own, licensed or component supplier equipment, plus after-market installers
* providers of basic positioning signals (eg: Loran-C, satellite) and established base station signals
* providers of communication equipment and services: private/public mobile radio systems, cellular telephone systems, satellite communications systems, ...
* suppliers of road side and central control components
* providers of contract system management and maintenance services.

A list of Canadian companies with R&D capabilities in these fields was prepared for the clients. The list was not very exhaustive; it was provided as a starting point for underta-

king possible further marketing or survey work on the supplier side of mobile information systems.

4.5 MARKET PENETRATION

When in-vehicle navigation/information systems become widely accepted will depend on numerous factors:

* functions and specific features offered (eg: as presented in the Interview Guide/Appendix H)
* performance and reliability of these features (written specifications & experiences by other users)
* other system characteristics: environmental robustness, portability, etc; and life-cycle cost (which includes purchase price).
* market factors
  - whether the devices are offered as options directly by the vehicle manufacturers, or only as an after-market installation
  - what competitors, within a given user community, are doing (eg: if U.S. based carriers, operating in Canada, offer services to customers made only possible by the navigation/information devices)
  - etc.
* the proportion of benefits that can be actually assigned to these systems, ie. share of increased efficiency, productivity, utility & comfort, enjoyment & awareness, road safety, security (driver/passengers/vehicle/cargo), conservation of resources, decreased barriers, etc.

During this study, a small (test) survey was undertaken to test/refine an interview guide and to get an idea about the needs and intentions of possible user communities (Section 4.3.2). The answers to a question about future needs were strikingly uniform (p.115); this perhaps explains, in part, why most respondents were reluctant to speculate about when these systems would be experimented with or implemented within their industries. Need for an initial exposure to the current and near term market offerings is clearly indicated.

The respondents were also asked to identify barriers that might hinder or slow down the acceptance of in-vehicle navigation/information systems. These would typically include:

- real or perceived increase in number and severity of traffic collisions and other incidents
- lack of coordination between system designers/developers and agencies who are interested in providing a broad range of services or who have very specific requirements (before systems can become useable/meaningful to them)
- threat to privacy ('big brother' monitoring location of vehicles and individuals) and to civil liberties/workers' rights (monitoring of employee performance by employers)
- threat of being fully charged for the use of roads based on time of day, length of use and number of passengers in the vehicle (seen as threat by many who now commute long distances alone in a car, in the middle of peak periods)
- liabilities due to inadequacies or defects in the main device, its components, system and applications software (eg. relating to turn instructions), or information transmitted from outside to the vehicle
- insufficient attention in design of hardware and software, and in mounting of the devices, to human factors (ergonomics and ease of use)
- psychological uneasiness by drivers about letting a potentially incomplete and unreliable system participate in any of the driving functions
- lack of national standards, or voluntary recommended practices (followed by manufacturers), that would have been developed on the basis of sound research
- cost of in-vehicle equipment, its maintenance and (fire & theft) insurance.

In the absence of legitimate market data, delphi panel technique is sometimes used to speculate about market penetration, or consumer acceptance, of future technology products. Such an effort, under the auspices of the 'International Institute of Applied Systems Analysis' (Ref 69), recently focused on expected developments in the road transport information systems field. This work, entitled 'A Delphi Panel-Derived Scenario on RTI Evolution', is summarized in Section 5.1.2/p123-127 of this report. The forecast of market penetration, from 1980 to 2080, is contained in Exhibit 29.

Another delphi study - undertaken in 1986 by Trevor O Jones of TRW Inc - predicted dates of introduction and 50% market penetration for some 54 truck-electronics systems (Ref: Fleet Owner/p.24&28, Dec 1986). The panel consisted of 36 experts in the fields of vehicle electronics, truck manufacturing and fleet management. He acknowledged that the 35 more likely systems would add about $12 000 to the cost of a truck - but 'if they can reduce truck operating costs by 7.4%, which I believe is feasible and readily achievable, they would pay for themselves in one year'. The findings of this panel are presented in Exhibit 28.

EXHIBIT 28

ELECTRONICS: WHAT'S COMING AND WHEN

A DELPHI STUDY OF 54 SYSTEMS

	PREDICTED DATES			
VEHICLE OPERATION	Intro-duction	50% of Units	Price $	Market $M
* Navigation	1990	1996	509	79
Precise location	1991	1998	582	91
Security - antitheft	1988	1993	239	37
* Security - locate stolen vehicle	1991	1995	323	50
* Automatic load advisory	1991	1997	432	67
* Automatic operation advisory	1991	1997	571	89
* Automatic weighing	1990	1995	432	67
Axle-load sensing	1989	1995	393	61
Cargo monitoring	1989	1994	343	53
Load-dispense control	1990	1995	434	67
Automatic load broadcast	1991	1997	397	62
* Communication system	1989	1995	468	72
VEHICLE CONTROL				
* Wheel-lock control	1988	1993	788	121
* Tire-pressure monitoring	1988	1994	300	46
* Road-condition monitoring	1991	1997	245	38
Headway monitoring	1991	1997	454	71
Headway control	1993	1999	919	144
* Automatic brake control	1992	1997	602	94
Electronically controlled strng	1992	1996	331	51
Automatic road-following strng	1997	2000	1029	154
* Steer by wire	1995	2000	650	102
* Aerodynamic surface control	1991	1994	416	64
Vehicle speed control	1987	1992	359	55
* Adaptive suspension	1990	1995	1033	160
* Coordinated tractor/trailer strng	1992	1998	1200	187
DRIVETRAIN CONTROL				
Engine speed control	1987	1991	427	63
Full engine control	1988	1993	666	102
Transmission control	1988	1994	588	91
Axle control	1989	1996	258	40
* Integrated drivetrain control	1990	1996	1017	158
PTO control	1987	1991	231	34
* Engine protection	1987	1992	214	33
* Remote engine control	1989	1995	214	33

	PREDICTED DATES			
INFORMATION & DISPLAYS	Intro-duction	50% of Units	Price $	Market $M
* Full digital displays	1988	1993	252	39
* Vehicle life-history recorders	1989	1994	374	58
* Crash recorders	1990	1996	348	54
* Service advisory & record	1989	1994	243	37
* Trip-data record	1987	1993	350	54
* CRT with maps	1990	1997	710	111
ELECTRICAL SYSTEM				
* 24v to 48v system	1990	1996	279	43
* Serial data link	1988	1994	223	34
* Multiplexing	1990	1995	250	39
COMFORT & CONVENIENCE				
* Cab-environment control	1988	1993	232	36
* Lighting control	1989	1994	116	18
* Seat control	1989	1995	122	19
* Rear-obstacle detection	1989	1996	204	32
5th-wheel hookup	1990	1995	189	29
* Mirror control	1988	1994	83	13
* Blind-spot detector	1990	1996	108	17
DRIVER-PERFORMANCE MONITORS				
* Physiological evaluation	1993	1999	250	39
Chemically impaired driver	1992	1997	236	37
* Fatigued driver	1991	1997	191	30
Erratic driver	1991	1997	207	32
* Skill evaluation	1992	1996	218	34

5. NATIONAL PROGRAMS

Concerns with traffic management have motivated government programs for assisting with the development of in-vehicle route guidance for about 20 years. Although originating in the U.S., stronger government roles based on traffic management needs developed in Japan, England and West Germany during the 1970s. Multiple government programs, often in concert with industry, have evolved during the 1980s in Japan and Europe. In Japan, these programs still focus on traffic management and communications and have generated an atmosphere of competition among government agencies. In Europe, safety and road transport informatics have become additional driving forces - and, as in Japan, there is some competition among government programs.

The U.S. government - FHWA (Federal Highway Administration) in particular - has been relatively inactive in the development of in-vehicle route guidance from 1970 until the past year. However, during the 1970's, UMTA (Urban Mass Transit Administration) took a very active role in the development and demonstration of automatic vehicle location monitoring systems (AVLM). In addition, several projects relating to mobile information systems have recently been undertaken under Canadian government auspices.

The objective of this section is to provide a description of government programs relating to vehicle location, navigation, and route guidance systems during the 1980s.

5.1 EUROPE

Automobile navigation, route guidance, communications and road transport informatics (RTI) have been the subject of numerous European programs, projects and studies that are nationalistic or multinationalistic in nature. Many of the programs involve cooperative arrangements among several government agencies and industrial concerns, and all of them have advanced the case for mobile information systems.

Some of the more important recent and current programs are discussed in alphabetical order in the following.

5.1.1 ALI-SCOUT/LISB

The ALI-SCOUT system, mentioned briefly in Section 2.1.2 and characterized in Exhibits 6b and 13, is a joint development of the West German government (Ministry of Transport & Ministry for Research and Technology), Siemens, Bosch/Blaupunkt, Volkswagen and others. Technical development is coordinated by Siemens which is responsible for the IR communication subsystems and the infrastructure equipment and software. Bosch/Blaupunkt is responsible for certain aspects of the in-vehicle equipment and Volkswagen collaborated in the development of the basic design concept which is an outgrowth of the earlier ALI and AUTO-SCOUT projects (Ref 24).

The initial role of the two ministries was to commission working parties to clarify various problem areas related to the introduction of ALI-SCOUT in terms of technical and traffic related problems, cost effectiveness, and legal and organizational preconditions. The working parties called for a large scale field trial of ALI-SCOUT in West Berlin to assess technical reliability, acceptance level, usefulness to road users and to estimate ultimate costs. Called LISB (for Leit- und Informationssystem Berlin, or Navigation and Information System Berlin), and scheduled to begin in 1988, the field test will involve 200 IR communication beacons and 800-1000 equipped automobiles divided among individual, business and institutional users. The total cost of LISB is estimated at DM 15 000 000, one half of which will be paid by industry with the remainder shared by West Berlin and the Federal Government.

ALI-SCOUT/LISB is now being connected to the PROMETHEUS project described in Section 5.1.8 (Ref 68).

5.1.2 ARISE/RTI-Delphi Study

ARISE, or the "Automobile Road Information System Evolution" project, was developed during 'The Future of the Automobile Program' which was started in 1980 by the MIT. The first

ARISE study was undertaken for the Swedish National Road Administration (SNRA) in the Spring of 1984. The first short report described the potential for benefits to society from establishing a data link between computers at the road-side and computers on-board vehicles.

A feasibility study was launched in 1985. It was decided that until the industry embarked upon the Road Transport Informatics (RTI) system idea, only long range systems analysis would be carried out. This was initiated at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria in early 1986. A contact network with concerned people and specialists in government, industry and research was established. In October, a decision (based in part on overlap with the much larger PROMETHEUS project described below) was made to discontinue the project at IIASA after completion of a Delphi study on how information technology, communication means and control systems can reshape future road traffic.

The Delphi study was carried out in two rounds with 54 responses in its first round and 31 responses in the second. An April 1987 working paper (Ref. 69) presented the Delphi results, the more important points of which are summarized as follows:

* Today's road transport problems can act as driving forces for seeking solutions for problem areas such as overall system economy, traffic and congestion growth, safety, etc.
* RTI is capable of alleviating some problems and improving road transport. Drastic improvements can be achieved if qualified technology and intelligent systems are introduced.
* Many system solutions are applicable. Benefits of one sub-system may be marginal but, as part of an integrated solution, that sub-system may yield larger benefits.
* There are few negative aspects, risks or pitfalls from introducing RTI. However, centralized and automated vehicle identification is perceived as a threat to personal freedom (privacy).
* Driving forces exist for developing RTI systems to high levels, provided they drastically reduce accidents, pol-

lution and traffic congestion while increasing driver comfort and transport economy.

Seven RTI categories were selected for assessing events:

- AVN = Autonomous Vehicle Navigation
- RSI = Road Service Information
- UCAD = User Cost and Automatic Debiting
- IRG = Interactive Route Guidance
- SDK = Speed and Distance Keeping
- CA = Collision Avoidance
- AHC = Automatic Highway Chauffeuring.

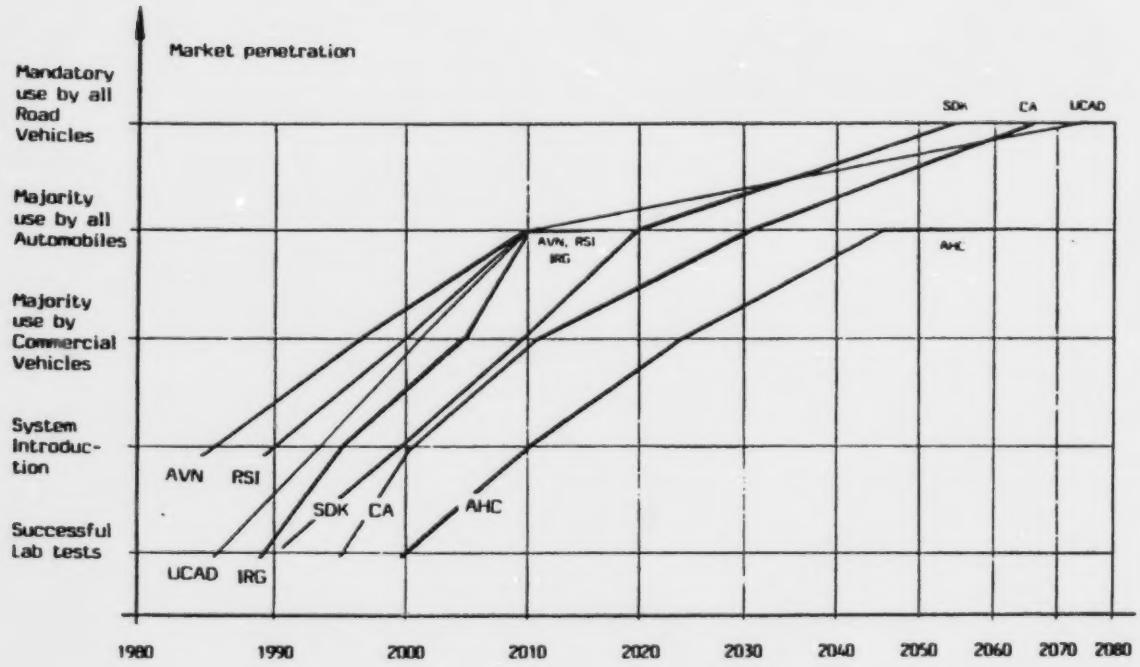
Different RTI categories can start at different times, proceed at different rates, and reach different market penetrations. Future market penetration is thought to pass through successful laboratory tests/pilot tests, commercial system introduction, majority use by commercial vehicles, majority use by all vehicles and, finally, mandatory use of the system in all vehicles. Median estimates of the year each of the seven RTI categories reaches each of these five stages of penetration are summarized in Exhibit 29.

The working paper includes estimates of the impacts of RTI implementation. All seven RTI systems can improve convenience, comfort and driver security. Lane capacity can be increased some 10% using either AHC or SDK systems. Traffic safety is expected to improve by 30% if CA systems are used, and some 42% if all RTI systems are implemented. RTI systems are expected to have only small impacts on emissions. The vehicle purchase price will, according to estimates, increase by 1% if a UCAD system is added, by 25% if an automatic chauffeuring system is added and by 5-10% each if an RSI, IRG, SDK or an CA system is added.

According to the panel's estimates, the information technology industry and the road administrations will be most influential in RTI implementation. Strong action is also expected from the trucking industry, company car owners and professional drivers. The commercial fleet market will be interested in RTI development before the private car owners are.

EXHIBIT 29

A DELPHI PANEL-DERIVED SCENARIO ON ROAD TRANSPORT INFORMATICS EVOLUTION



Key:

AVN	Autonomous Vehicle Navigation
RSI	Road Service Information
UCAD	User Cost and Automatic Debiting
IRG	Interactive Route Guidance
SDK	Speed and Distance Keeping
CA	Collision Avoidance
AHC	Automatic Highway Chauffeuring

Source: Ref 69

Cost is assumed to be the main barrier for RTI. If initial investment costs and/or systems operating costs are too high, a mass market for RTI system will not develop.

5.1.3 Autoguide

In 1986, the U.K. Department of Transport proposed a project to develop and demonstrate Autoguide, an interactive route guidance system designed by the Transport and Road Research Laboratory (TRRL) (Section 2.1.2 & Exhibits 6c and 13). Autoguide was promulgated by a discussion document (Ref 25) which claims, "the proposed system fits well with the Government's intention to pursue improved driver information on London's roads", and notes that "working with other countries can lead to many advantages".

In 1987, project officials concluded that Autoguide's inductive loop communications beacon approach should be replaced by the IR beacon approach used by ALI-SCOUT in West Germany pending outcome of early trials. A joint UK/West German working party was then established to define a draft international standard for infrared road-vehicle communication.

Initial cost estimates by TRRL indicated that full implementation of Autoguide out to M25 in London would cost on the order of £15-20M for the infrastructure (ie: roadside beacons, communications and control centres), and would have annual running costs of £2-3M. Equipment for user vehicles would cost perhaps £150 and, assuming 400 000 users, each might pay £20-30 annually to defray installation and operating costs. It is the intention of the government that the cost of Autoguide be ultimately borne by the private sector.

A small scale demonstration of Autoguide was implemented in a Heathrow Airport to central London corridor in the Spring of 1988; proposals are now being solicited for a pilot stage installation covering much of London. Like ALI-SCOUT/LISB, Autoguide is now being linked to the PROMETHEUS project described below (Ref 68).

5.1.4 CARMINAT

CARMINAT is one of 165 projects under EUREKA, a European research cooperative established in 1985 by a Conference of Ministers of 17 countries and Members of the Commission of the European Communities with the objective of raising, through closer cooperation among enterprises and research institutes in the field of advanced technologies, the productivity and competitiveness of Europe's industries and national economies on the world market. In addition to CARMINAT, many other EUREKA projects - including PROMETHEUS, DEMETER, EUROPOLIS, TELE ATLAS and ERTIS - relate to automotive navigation and route guidance.

CARMINAT primarily unites CARIN, the Philips automobile navigation project (Ref 42), with SAGEM'S MINERVE modular information concept based on on-board mass memory, and with ATLAS, Renault's automobile information project which has been pursued since 1982 in cooperation with Telediffusion de France (Ref 70). The ATLAS automobile information project includes system design features for:

* sensed endogenous information: speed, fuel level, alarm conditions, maintenance needs, diagnostics, overall mechanical status, etc.
* on-board information stored in interchangeable mass memory, eg: user's manuals, driver automobile ID, maintenance records, driver personalization of electric-powered seats (radio stations, volume, etc), and map collections with tourist information
* exogenous information received from outside the car including traffic information and facilities information.

The synergy between these different types of information is illustrated by the combination of remaining gasoline (endogenous information), vehicle location, maps including service station network (on-board information), and opening hours of local service stations (exogenous information) to answer the question, "I'm almost out of gas - what should I do?"

ATLAS assumes the most likely candidate for transmission of exogenous information to automobiles is RDS (Radio Data System), an approach also promulgated by Philips for transmit-

ting traffic data, weather conditions, road surface conditions, etc. to CARIN (Ref 42). RDS test broadcasts are currently taking place in France, West Germany, Sweden, England as well as in the Netherlands where traffic data is already being transmitted experimentally. RDS has the advantage of using existing FM radio transmitters without changes to the infrastructure (unlike the communications beacon approach required by Autoguide and ALI-SCOUT/LISB).

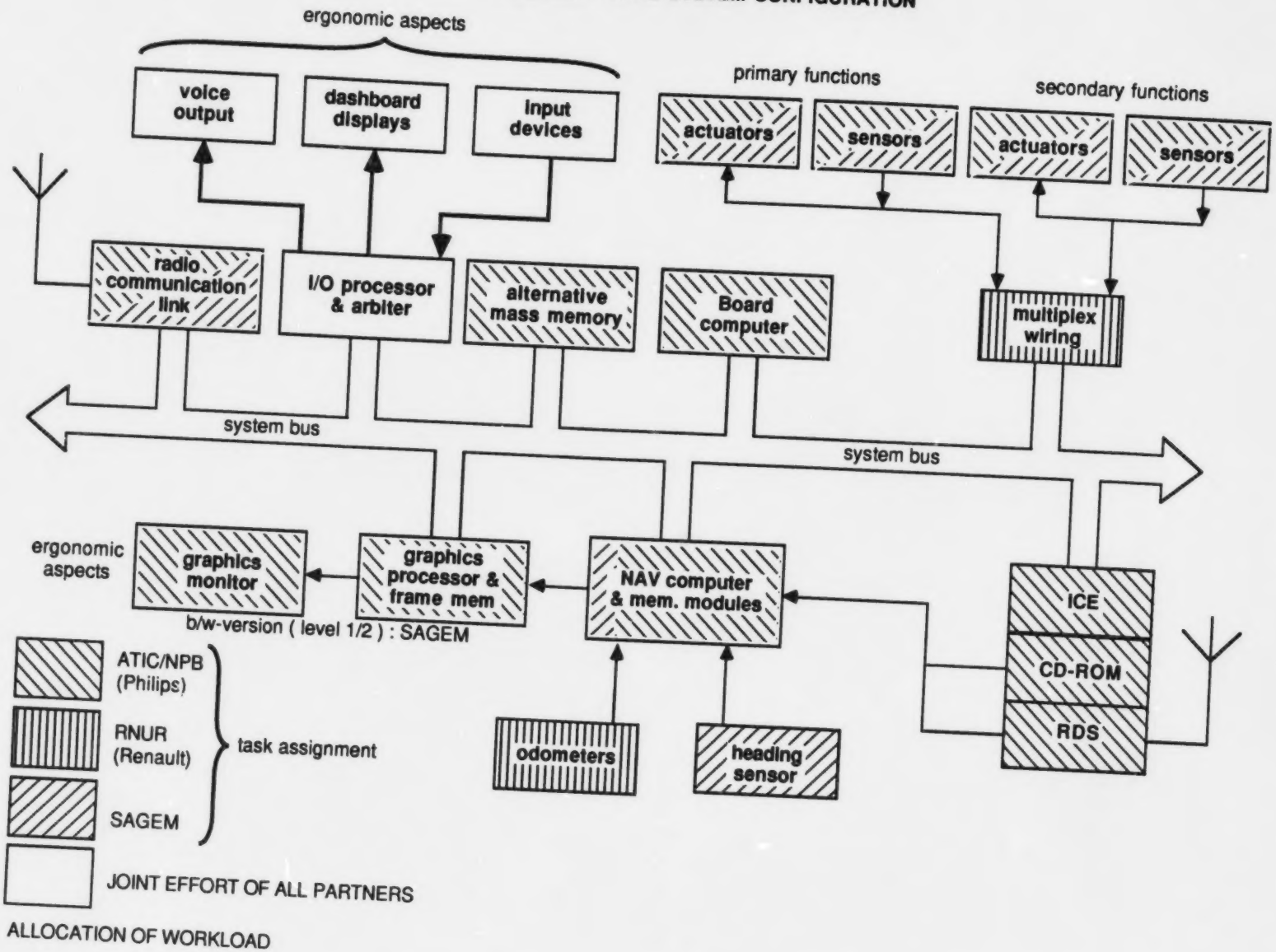
Integration of CARIN technology with MINERVE and ATLAS yields the CARMINAT total systems approach for navigation, communication and vehicle diagnostics. The total system configuration and the allocation of workload among the participants is presented in Exhibit 30 (source: EUREKA proposal establishing CARMINAT). Preliminary plans call for Philips, Renault, SAGEM and TdF to collectively expend 52 million ECU's, including 351 man-years, on CARMINAT development and full prototype testing through 1989.

5.1.5 COST 30

In 1984 the EUCO-COST 30 bis Working Group 1 of the Organization for European Cooperation in the Field of Scientific and Technical Research - which included representatives of England, France, Netherlands, Sweden and West Germany - published a final report which examined systems approaches, economic potential, and standards considerations (Ref 61). Entitled "Road/Vehicle Electronic Communications: Electronic Traffic Aids on Major Roads", the report concluded that the most practical approach from the implementation viewpoint would be vehicle-borne navigation aids in combination with area-wide one-way (infrastructure-to-vehicle) communications. The group recommended further international collaboration to identify a suitable broadcasting channel, and encouraged sharing facilities with an existing broadcasting system such as RDS or cellular radio.

EXHIBIT 30

CARMINAT TOTAL SYSTEM CONFIGURATION



5.1.6 DEMETER

DEMETER is an EUREKA project with the primary goal of establishing a European standard for the contents and structure of digitized geographic information. The standard will be structured so that geographic information can be used for various applications such as cartography, educational purposes, and planning activities, as well as in vehicle navigation. Other goals include the coordination of R & D on production methods and equipment for digital maps in concert with the standard, and the production and testing of prototypes of digital maps of parts of Europe.

DEMETER started late 1986 with a definition phase for the specification of digital navigation maps and will include preliminary field tests to validate the specification. The definition phase will be followed by a prototype phase for production and testing of digital maps. The initial participants, Philips and Bosch/ Blaupunkt, are contributing resources to carry out the tasks of the definition phase and prototype phase. Other participants will carry out the actual production of the initial geographic data base during the prototype phase of the project. The final goal of DEMETER is to enable the start of commercial production of digital maps in 1989 so that standardized geographic data on Compact Disc will be available in 1990.

According to Bosch/Blaupunkt, work on the standard to date uses topology definitions (0 cell, 1 cell, etc.) that are compatible with those proposed by the National Committee for Digital Cartographic Data Standards (Ref 60). Early emphasis is on establishing an efficient data exchange format.

5.1.7 DRIVE

DRIVE (Dedicated Road Safety Systems and Intelligent Vehicles in Europe) was started in 1986 (European Road Safety Year) by the European Commission with MVA Systematica (U.K.) as management contractor. The objective was to assess if information and telecommunication technology could make a major contribution to the improvement of road safety (Ref 71).

Four expert studies were carried out:

* On-board Safety Systems - Consultronique (France)
* Vehicle Guidance and Communication - Blaupunkt (West Germany)
* Urban Traffic Control for Road Safety - GEC Traffic Automation (England)
* Motorway Traffic Control for Road Safety - Autostrade (Italy)

A wide range of technologies were assessed including route guidance, hazard warning, collision detection, speed control, driver interface, automatic chauffeuring, and highway management information systems. Three kinds of navigation and route guidance systems were considered:

* on-board dead-reckoning with (infra-red or microwave) communications beacons to provide real-time dynamic route guidance (eg: Autoguide, ALI-SCOUT)
* on-board dead-reckoning with an on-board CD-ROM map to provide autonomous route guidance based on static information (eg: CARIN, EVA)
* land-based radio-location beacons primarily concerned with vehicle security and location monitoring (eg: DECCA, OMEGA, LORAN-C).

The main conclusions and recommendations drawn from the study fell into several groups, of which standardization and basic research were paramount. A report presented at the DRIVE Seminar in Brussels in September 1986 included primary recommendations related to standardization in the navigation and route guidance area:

* standard definition of location
  eg: European digital maps
* standard methods of communication
  eg: infra-red beacons, RDS, mobile cellular, etc
* standard traffic messages
  eg: coding of names, events, routes, etc.

In addition to the standards work, DRIVE recommended basic research related to the automatic chauffeuring requirements of machine vision and vehicle control software.

Little progress has been made since September 1986 because DRIVE, as part of the European Commission's FRAMEWORK program

for Community-supported research under the control of DG XIII, had been blocked until October 1987. DRIVE will now probably be directed towards serving the needs of an interoperable European RTI (Road Transport Informatics) infrastructure, leaving PROMETHEUS (see below) with emphasis on the related on-board components. DRIVE held workshops in Brussels in October 1987 on several subjects related to RTI infrastructure to help specify its new objectives and activities.

5.1.8 PROMETHEUS

PROMETHEUS ("**PRO**graM for a **E**uropean **T**raffic with **H**ighest **E**fficiency and **U**nprecedented **S**afety) originated in mid-1986 as an EUREKA project. Its ultimate objectives are to make (year 2000) road traffic better moving, quicker, more economical, and with fewer environmental consequences and far fewer accidents.

The following European automobile manufacturers are participating in the project:

* Matra, Peugeot and Renault (France)
* BMW, Daimler-Benz, Porsche and Volkswagen (West Germany)
* British Leyland and Rolls-Royce (U.K.)
* Alfa Romeo and Fiat (Italy)
* Saab, Scania and Volvo (Sweden).

In addition to those automobile manufacturers, some 50 research institutes also participated during the one-year definition phase. PROMETHEUS is directed by a multinational steering committee and includes seven research areas as indicated in Exhibit 31.

The definition phase, which was concluded in October 1987, included specific related work already underway:

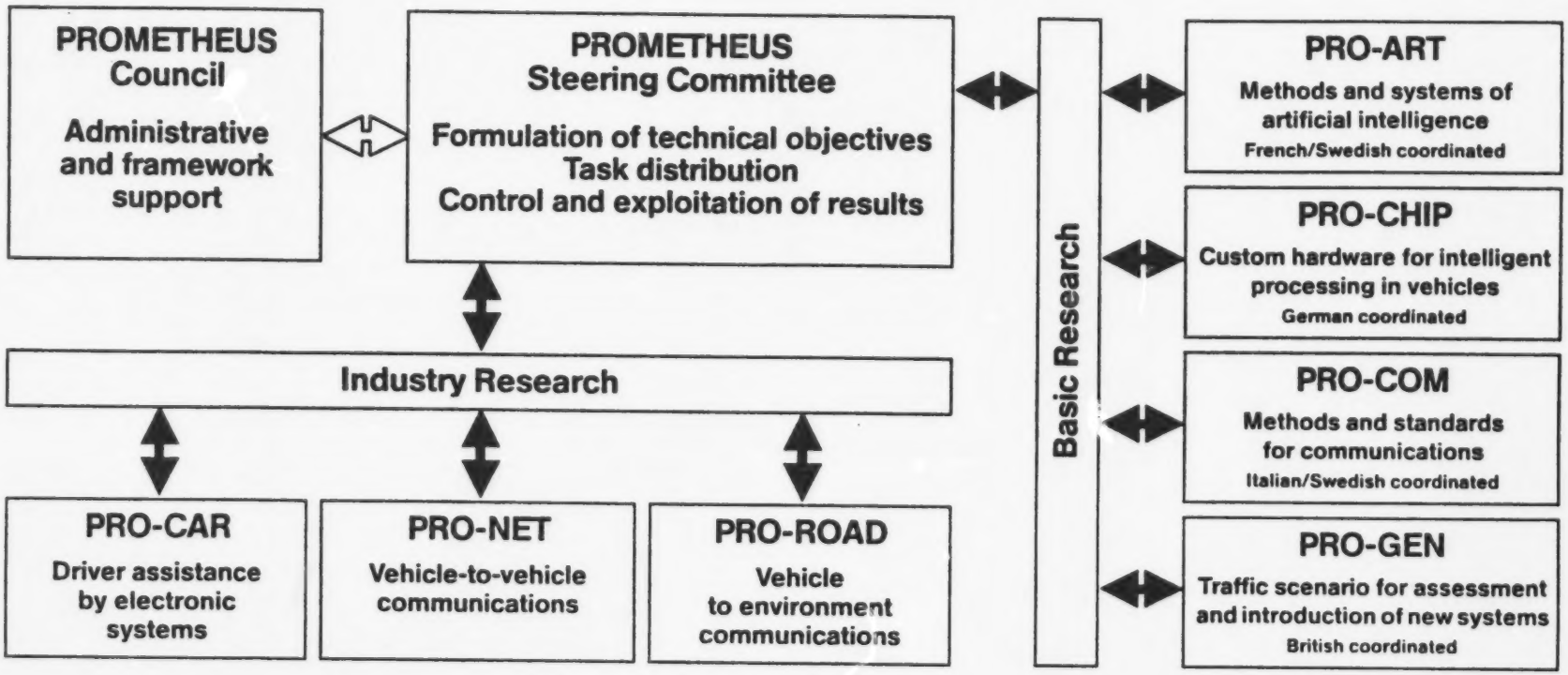
* anti-locking brake system which prevents dangerous locking of the tires during braking
* limited-slip-differential control, by which the rotation of driving gears is instantaneously avoided
* electronic engine control (assigned to the Bosch group)

EXHIBIT 31

PROMETHEUS ORGANISATION

PROMETHEUS Organisation

PROMETHEUS
Brussels
Nov. 30th, 1987



* instrument design (assigned to VDO)
* other automobile manufacturers and enterprises have dedicated themselves to automatic navigation, ie:
  - Daimler-Benz with its 'rolling' map
  - Volkswagen and Blaupunkt with their electronic guidance systems, ALI and EVA
  - Siemens, which already previously had developed an on-board computer for BMW, with its SCOUT system
* 'electronic features-package' which consists of gap-radar, vehicle-to-vehicle communication capability, and electronic accelerator pedal (Daimler-Benz).

However, one of the first outcomes of PROMETHEUS is likely to be a harmonized approach to route guidance. In particular, PROMETHEUS is now recognizing the significant prior research and development on infrastructure-supported navigation systems such as Autoguide in the U.K., ALI-SCOUT/LISB in West Germany, and the related RTI activities of DRIVE. Since the motor industry needs to build vehicles which can operate in cities throughout Europe, PROMETHEUS will be taking an active role in promoting standardization in the area of vehicle communications, protocols and data formats as well as in developing a common European digital map (Ref. 68).

Future progress toward achievement of the PROMETHEUS goals is expected through the combined efforts of the automobile manufacturers and the European electronics and component industries which are being invited to join the project early in the second phase. A PROMETHEUS symposium was held in Brussels 30.11-1.12 1987 to brief representatives of the electronics and component supplier industries and initiate their participation.

On the first day an overview of the PROMETHEUS Program was presented to first line managers of companies interested in collaboration, as well as to representatives of governments and associations from EUREKA member countries. On the second day, functional descriptions of research fields were presented by the automotive industry for future research work to be undertaken in collaboration with other industries and research institutes.

Initially funded at $15.3M/year, the costs are expected to approach $55M/year, giving a total budget of almost $400 million. This will be shared by the 13 automobile companies and their respective governments.

5.2 JAPAN

More than 50 Japanese companies have joined with the government to develop a behind-the-wheel computer system that will tell drivers their location and suggest alternative routes for avoiding traffic jams. This includes all auto companies and many other industrial giants, such as Sony, NEC, Sumitomo Electric Industries and Mitsui. The Japanese hope to forge national standards (to avoid the BETA/VHS type problems), and create a product more quickly by linking such diverse industries as automobile manufacturing and telecommunications at the research stage. The government is giving out the basic data, university professors are consulting, electronics makers are co-operating on data transmission systems, and auto makers are working on applications.

However, bureaucratic problems also abound: the Construction Ministry and the National Police Agency are each pushing for rival systems. They have organized separate groups to pursue research - but, incredibly, membership of the rival groups is almost the same. The rival location systems are based on dead reckoning with radio signals from roadside beacons in one case and from sparsely positioned tele terminals in the other case. Both approaches incorporate map-matching; signals from satellites may also play a role in future systems.

The Japanese national programs and the roles of the participating government agencies are discussed in the following.

5.2.1 ATICS

The ATICS (Automobile Traffic Information and Control System) project was designed to upgrade current traffic control systems by applying new technology and methods in the development of a comprehensive traffic control system. The project -

carried out under the National Police Agency (NPA) 1978 through 1985 - addressed three interrelated areas:

* traffic information transmission systems
* traffic signal control systems
* total systems.

The traffic information transmission research addressed the problem of providing drivers with up-to-minute detailed information which can help guide and disperse traffic flow. Approaches considered included variable roadside display panels and roadside transmitters in conjunction with voice conversion devices mounted in the vehicles. Research on traffic signal control methods included new means for traffic flow detection. Results of field tests indicated that ultrasonic detectors for vehicle discrimination, optical traffic meters and simple Doppler vehicle detectors have excellent potential as innovative detectors with high applicability.

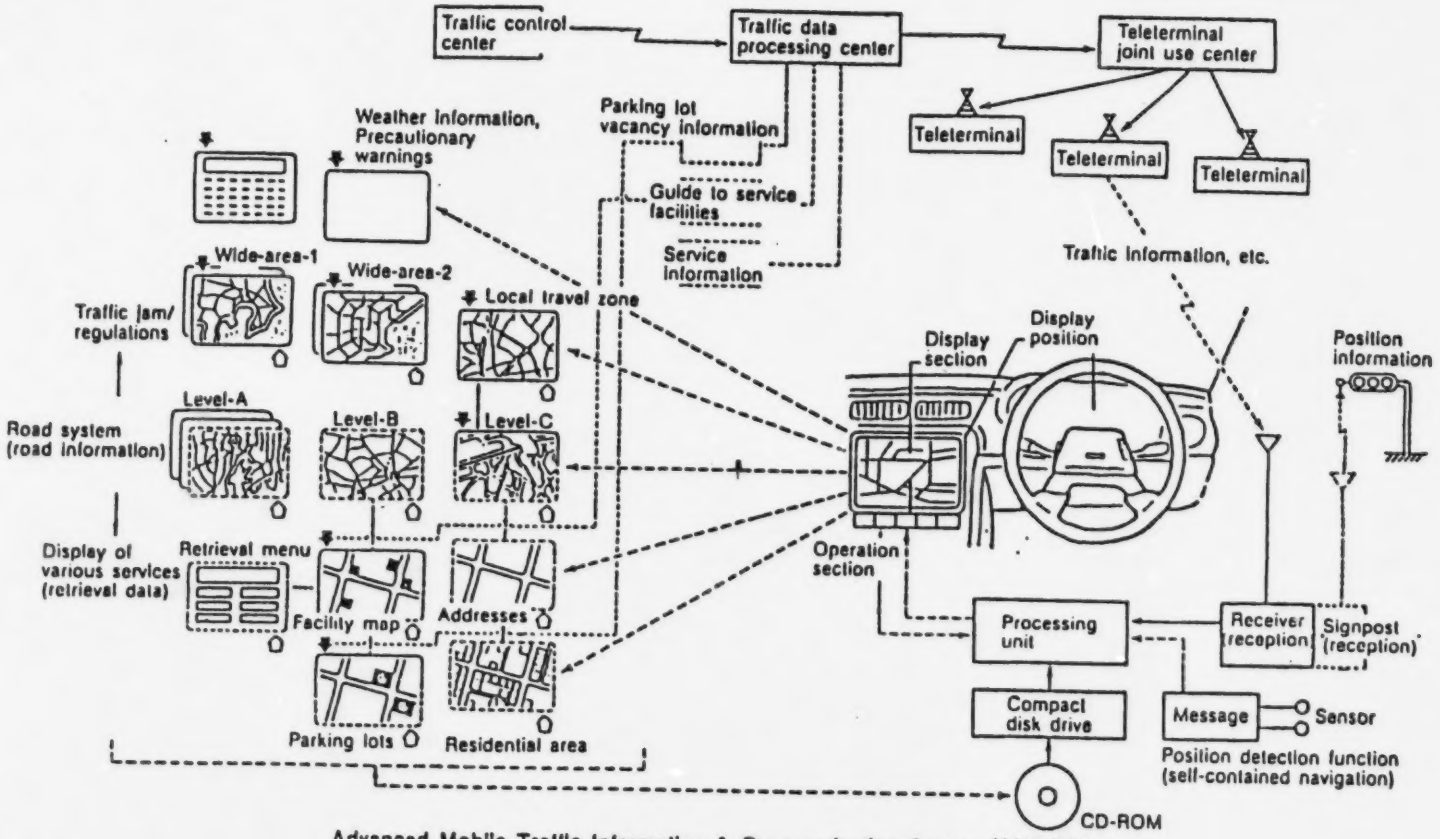
ATICS research on total systems included how to make practical application of route guidance systems based on communications from both in-vehicle equipment and roadside equipment. It was concluded that a centralized study which includes development of a traffic guidance algorithm will be required in the future. It was also recommended that further study of traffic guidance systems must take into account the fact that the proportion of vehicles carrying devices has a marked influence on the amount of information obtained and on system efficiency.

5.2.2 AMTICS

AMTICS is the acronym for the "Advanced Mobile Traffic Information & Communications System" project which was set up through the Japan Traffic Management and Technology Association by the National Police Agency (NPA) in cooperation with the Ministry of Posts and Telecommunications (MPT) at the beginning of 1987. AMTICS has the objective of providing onboard traffic and navigation information by integrating a variety of subsystems as shown by the overall conceptual diagram in Exhibit 32 (Ref 72).

EXHIBIT 32

ADVANCED MOBILE TRAFFIC INFORMATION AND COMMUNICATION SYSTEM (AMTICS)



Advanced Mobile Traffic Information & Communication System (AMTICS)

Source: Ref 72

A display screen in each car will show traffic information gathered by the police at traffic surveillance and control centers in 74 cities. The information will be processed at an AMTICS computer center and broadcast to cars using the new "Teleterminal" data communication system being promoted by MPT. The 800 MHz Teleterminals have a range of approximately 3 km and will be installed in a mesh network. "Packet" data transmission technology will be used, and there will be a capability for addressing data messages to individual receiving vehicles. The vehicular equipment will include CD-ROM for stored maps and software for computing and superimposing car position based on self-contained navigation sensors and, possibly, received from proximity beacons.

Following a study report issued 27 April 1987 by the AMTICS research group, an AMTICS development and promotion council was established which now has more than 50 industry participants who pay substantial membership fees. An experimental pilot system is planned for 1988 with the first commercial system to be in operation in 1991. AMTICS is somewhat competitive with a similar systems approach which has been researched and promoted by the Ministry of Construction (MC) since 1984.

5.2.3 HIDO

HIDO (Highway Industry Development Organization) was established under the auspices of the Ministry of Construction in 1984 to undertake research, investigation and development of new industrial fields related to highways in order to render service for the development of highway functions, maintenance and extension. HIDO quickly organized a Car Communications Committee chaired by Dr S Takaba (Tokyo University) and composed of manufacturers, surveyors and representatives of other related fields. The Car Communications Committee coordinates research and development leading to a Road and Automobile Communication System which can provide navigation, information service and communications for drivers.

The system concept promulgated by HIDO's Car Communications Committee is composed of three subsystems; navigation, road-

side beacon signposts, and individual communications. The overall systems diagram is shown in Exhibit 33. In 1986, the Public Works Research Institute (PWRI), also under the Ministry of Construction, started a 3-year joint study and experiment with car manufacturers and electronic device manufacturers in order to put this system into practical use.

The first field experiments on static navigation were performed in March 1987 using inductive radio type beacons in conjunction with a digital map of 350 km^2 including parts of the Tokyo and Yokohama districts prepared by PWRI. The experiment involved nine different in-car navigation devices developed by private companies including Sumitomo Electric, Nissan Motors, NEC Corporation, Nippondenso, Matushita, Mitsubishi, NEC Home Electronics, and Yazaki. Navigation device development is being continued by each company and PWRI is revising the digital map for further field experiments early in 1988. Map matching tests are to be carried out using the improved map, and dynamic information on traffic congestion will be added to the communications beacon transmission.

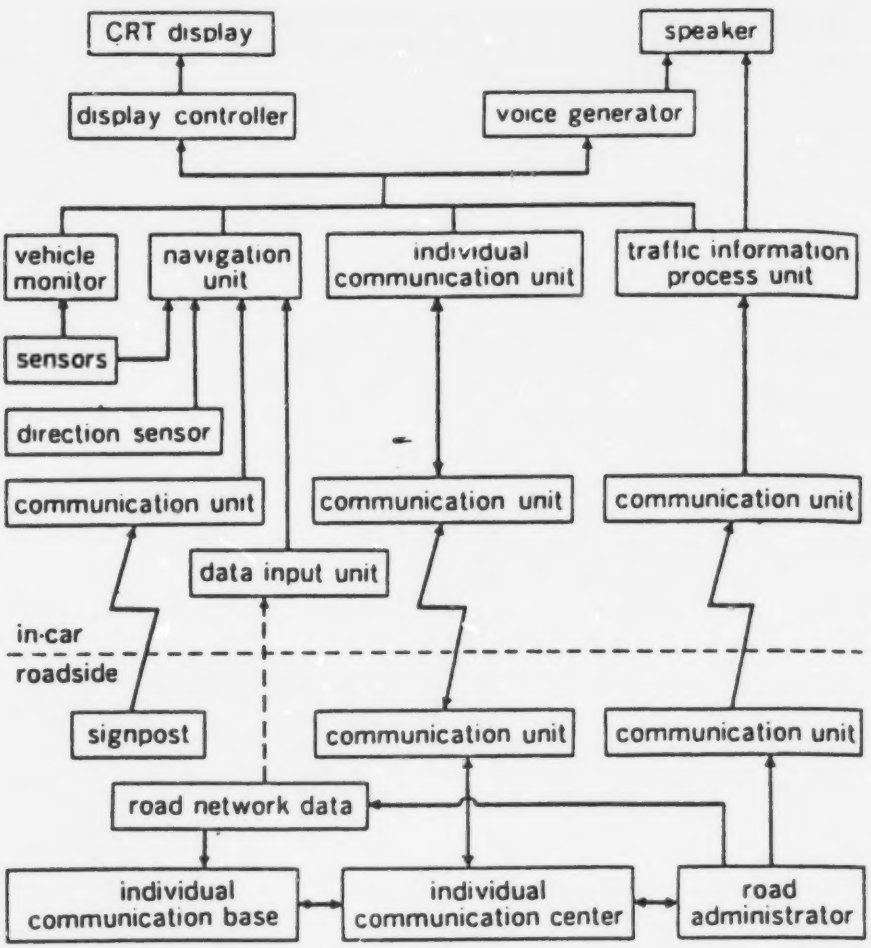
5.2.4 JSK

The Association of Electronic Technology for Automobile Traffic and Driving (JSK) is a non-profit foundation which is controlled exclusively by the Ministry of International Trade and Industry (MITI). This organization was responsible for the development of CACS, the in-vehicle route guidance system tested during the 1970s as described in Section 2.1.2. (Ref 22). JSK's continuing activities include several tasks:

* popularize the technological results and experience of the CACS project to related organizations and fields
* develop and test protocols for inductive radio communications
* research automobile traffic and driving in the future information-oriented society with the goal of improving the automobile traffic system
* provide and appraise future policy options for efficient automobile information systems from a technological viewpoint

EXHIBIT 33

MC/HIDO PROPOSED IN-CAR INFORMATION SYSTEM



* promote the development of road-automobile systems through joint study groups, seminars, symposia, etc.

Current JSK thinking regarding promotion of automobile informatics is to start with buses, trucks and business cars used by salesmen, etc. To check this possibility, a case study, including hardware development, presentations and consultations with users and entrepreneurs, is planned for a certain local district.

The most recent JSK undertaking is an investigation of the state-of-the-art concerning automobile navigation and related R&D throughout the world. A mission including representatives from academic and industrial organizations is being planned to visit activity centers in Western Europe and North America in 1988. Topics to be discussed include ways of promoting R&D programs, strategies for bringing systems into practical use, and the possibility of international cooperation for coordinating hardware and software specifications.

5.3 NORTH AMERICA

At present there are no national programs per se on vehicle navigation and information systems in North America in the same sense that such programs exist in Europe and in Japan. There are, however, several relevant projects and studies that have been performed, or sponsored, by government agencies in the United States and Canada during the 1980s, and there is one relatively new U.S. initiative that could evolve into a national program for automobile navigation and route guidance.

5.3.1 AVL 2000

A research team in the Department of Surveying Engineering at the University of Calgary has a grant from the Natural Sciences and Engineering Research Council of Canada to develop and test a prototype automotive vehicle location system called "AVL 2000" (Ref 73). The objective is to help define problems and identify solutions, primarily with on-road land applications.

The AVL 2000 system is an in-vehicle real-time system which utilizes an integrated positioning system to, first, locate a moving vehicle and then have its position superimposed on a digital route map displayed on a CRT. The first phase of development was to assemble a prototype from existing hardware. The hardware consists of a Trimble 4000S GPS satellite receiver and a MACPLUS micro-computer with a graphics display all mounted in a van. The software consists of a control program, map and route data bases, as well as data bases for auxiliary and collected data. A "best route" determination scheme is part of the AVL 2000 prototype system. Several field tests were underway with the AVL 2000 system in 1987.

The second generation of the AVL 2000 system is conceived as being an AVL system which will use the latest advancement in both hardware and software components. As such it will be a micro-processor-based AVL system, and its software will be based on heuristic principles instead of being entirely algorithmic. It will also be an intelligent-customized AVL system in which state-of-the-art VLSI design and architecture will be used.

5.3.2 IVRG Feasibility Study

In the late 1970s, Sperry Systems Management was awarded a contract to perform an In-Vehicle Route Guidance (IVRG) Feasibility and Design Study for the FHWA. The purpose of the study was to determine whether in-vehicle route guidance can satisfy a socioeconomic need in a cost-effective manner and, in the process, to define the design and system deployment characteristics which a cost-effective system would require.

The study report (Ref 18), issued in May 1981, indicated that the majority of route guidance needs relate to urban areas and that a significant "excess" in travelled time and distance is present. It was concluded that there is significant improvement potential for IVRG, and that cost-effective IVRG systems may be implemented over a fairly wide parametric range of urban geographies. To be effective, a system must provide "strategic guidance" to plan and control a trip,

rather than just provide a local guidance assist at individual points or at a limited series of points.

A spectrum of system designs was synthesized and analyzed using both two-way communications between the vehicle and roadside and one-way roadside to vehicle communications with message selection in the vehicle. The study results favored an IVRG system which used one-way data transmission to the vehicle by optical or microwave communication. Analysis showed good benefit-to-cost ratios providing that in-vehicle equipment cost is sufficiently low. The report claimed that the vehicle equipment cost for appropriate demand generation appeared to be within a range which was technically feasible. A major negative factor was the high initial outlay required for a fairly complete infrastructure installation before it could become useful and attractive to motorists in a given urban area.

It was recommended that a phased program be planned to further refine the design, cost, market assessment and public acceptance issues. The final objectives of the recommended program was a large-scale operational field test for quantitative benefit, public acceptance, technical and market assessments.

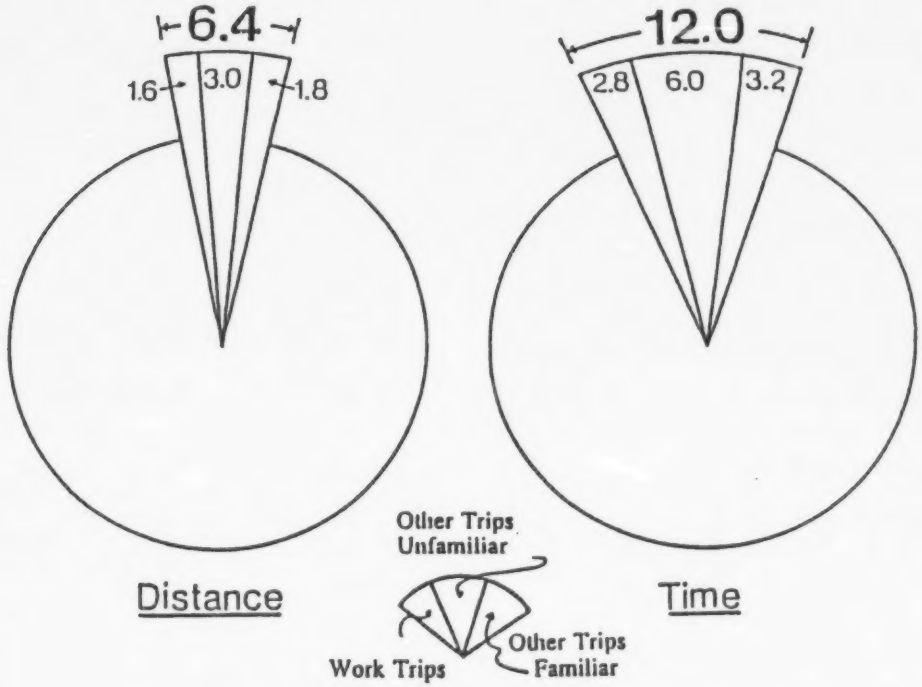
5.3.3 Route Following Economic Assessment

The FHWA subsequently contracted with KLD Associates Inc, to quantify the extent of excess travel time due to inefficient highway navigation for non-commercial vehicles in the United States in terms of both distance and time. The resulting economic assessment found that recoverable navigation waste amounts to 6.4 percent of all distance traveled by non-commercial vehicles and 12 percent of all time spent in such travel (Ref 74). The annual cost to individuals and to society of this excess travel was estimated at $45.7 billion considering only vehicle operating and accident costs and the value of time. Key results are summarized in Exhibit 34.

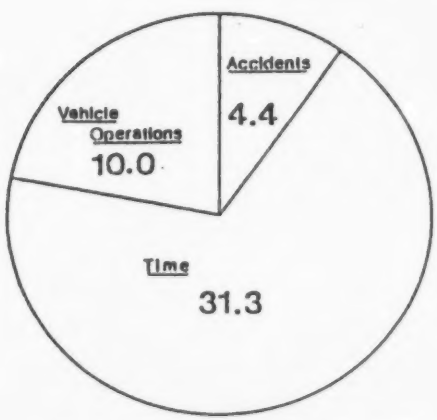
It follows that if a significant fraction of vehicles were outfitted with effective navigation aids, their diminished demands on roadway capacity would contribute to improved

EXHIBIT 34

NAVIGATIONAL WASTES IN THE UNITED STATES



a. Percent Excess Due to Navigational Waste



Total — $ 45.7 Billion

b. Costs of Navigational Waste

traffic conditions as well as great economic savings. Automobile navigation systems with routing or guidance functions are even more effective if current information on traffic conditions is available for consideration in routing. In a separate paper, G E King, the Principal Investigator in the FHWA study, estimated that the potential savings from eliminating navigation wastes increases to $73.6 billion annually if real-time traffic information is available to on-board route guidance systems (Ref 75). Traffic flow would also be enhanced by route guidance systems that responded dynamically to current conditions to avoid congested areas, thus contributing to balanced traffic management.

5.3.4 HELP Project

The Heavy Vehicle Electronic License Plate (HELP) System is an integrated truck traffic monitoring system. It combines automatic vehicle identification (AVI), weight-in-motion (WIM), and automatic vehicle classification (AVC) technologies with a computerized data communications network (Ref 76). With funding assistance from the FHWA, a group of western states have come together to form the nucleus and the driving force behind the HELP system development program. These include the states of Texas, New Mexico, Arizona, California, Oregon, Washington and Nevada, as well as Alaska, Iowa and other states and Canadian provinces.

The overall aim of the HELP Development Program is to produce a system which will bring the maximum benefits to states and truckers at least cost. Within this framework, the detailed objectives are to:

* fully explore the public and private applications of HELP, in order that the system is configured to be of greatest use to the greatest number
* develop an automatic vehicle identification system specification which produces the required characteristics in a HELP system context
* develop performance specifications for the weigh-in-motion and automatic vehicle classification components of the HELP system

* investigate related technology areas which could be used to supplement and enhance the HELP system
* produce an overall system design which takes account of user needs, and institutional, technical and economic constraints
* develop a site location strategy which will locate HELP sites for maximum utility and greatest economic benefit
* undertake an operational assessment of the fully developed HELP system in a realistic multi-state implementation (the Crescent project)
* evaluate the benefits of the fully developed HELP system from operating experience in the Crescent project.

The HELP system will give the trucking industry information needed for fleet management and control, business planning and tax compliance. It will give government information needed for facility planning and management; vehicle taxation; size, weight and speed enforcement; crime detection; and monitoring hazardous materials movements. It will also reduce administrative time and effort for both states and truckers at ports of entry and weigh stations.

The HELP System Development Program will demonstrate the viability of the HELP System concept and will provide a realistic assessment of both costs and benefits. It involves:

1) developing and testing HELP System hardware, software, and institutional arrangements; and
2) installing and evaluating the HELP System on a major truck route running from British Columbia to Southern California, and from there to Texas.

5.3.5 WAVM Study

The Wide Area Vehicle Monitoring (WAVM) system is an application of satellite navigation and communications technologies that will be capable of operating from coast to coast in North America. It will provide vehicle position data and two-way communications services between the equipped trucks and the trucking company's base station and thus provide an important link, which is missing currently, between the trucking companies and their fleets. The system will be a powerful

new tool for the trucking companies to optimize asset utilization and improve vehicle productivity.

Recognizing the potential of WAVM system technology, Ministry of Transportation of Ontario (MTO) initiated a WAVM system project to promote the applications by the Ontario trucking industry (Ref 77). Due to the enthusiastic responses from the industry, a joint demonstration project group consisting of trucking companies, high technology service and equipment suppliers, and MTO was planned and organized. The purpose of the WAVM project group is to demonstrate the WAVM system applications in the truck fleet sector and to promote this high technology product opportunity to the industry.

The WAVM system uses a microprocessor-based vehicle sub-system (on-board unit) to provide truck position locating capability and truck-to-base-station two-way communications capability. The vehicle subsystem will consist of a WAVM mobile data terminal (for control & display) connected with GPS user equipment and a mobile satellite communications terminal. Based on the GPS satellite signals, the GPS equipment will continuously compute and update the truck's position and velocity data, which will be transmitted by the mobile satellite communications terminal. At the WAVM base station, a micro-computer system with a communications device and a graphic/alphanumeric display unit would communicate with the trucks in the field through MSAT channels or cellular radio channels to receive truck identification, position and velocity information and to transmit messages to direct the trucks in the field. The truck fleet manager at the base station would have the real-time information on the identity of the trucks, the location of the trucks, where the trucks are going, and what they are doing (eg: speeding or idling).

The proposed WAVM system would allow trucking companies to improve their operational efficiency and safety in general goods distribution and to keep track of valuable or dangerous cargoes. Knowing exactly the overall operating status of the truck fleet at any given point in time, the truck fleet manager could select or devise the optimum operating plan or schedule to maximize operation efficiency, safety and profit. The WAVM system is expected to become an effective tool for

the truck fleet operating agencies in improving their daily operation control.

5.3.6 NCHRP Project 3-34

In November 1985, the NCHRP - National Cooperative Highway Research Program, a unit of the Transportation Research Board which administers research projects sponsored by the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration - awarded a contract in the amount of $399 98[illegible] to Arthur D Little Inc to research "The Feasibility of a National Heavy Vehicle Monitoring System". The following synopsis is based on the interim report (Ref 78).

The scope of Heavy Vehicle Monitoring (HVM) treated in the study includes the following technologies and pertains to trucks with gross weight greater than 26,000 lbs:

* weighing in motion (WIM)
* automatic vehicle classification (AVC)
* automatic vehicle identification (AVI)
* automatic vehicle location (AVL)
* on-board vehicle management systems (VMS).

The objective of the research was to answer the following questions:

* Is there sufficient market to warrant a national HVM system?
* Is appropriate technology available?
* What are the legal and institutional ramifications?
* What are the HVM system alternatives?
* What are the impacts, costs and benefits?

The approach used for the research included interviews with affected individuals, market surveys of motor carriers and owner-operators, surveys of state agencies, technical literature review, and review of statutes and case law regarding legal ramifications. Also included was the generation of al-

ternative HVM scenarios encompassing different markets, technologies and levels of participation.

The study concluded that a national HVM system is technologically feasible and that there is a viable market for HVM information. However, the market in highly fragmented with each submarket having unique requirements. Consequently a single integrated national HVM system is not institutionally feasible at this time because there is no concensus among government or motor carriers on the needs for a single system.

The interim report recommends that public and private sectors should encourage development and application of HVM systems within specific markets, and promote standardization to unify and enlarge the markets. Extensive market data is included in the interim report. An example is given by Exhibit 35.

5.3.7 NCHRP Project 3-38(1)

This 2-year, $200 000 research project, entitled "Assessment of Advanced Technologies for Relieving Urban Traffic Congestion", was initiated 1 July 1987 with Castle Rock Consultants as the contractor. The objectives are to:

1) identify and assess the most promising advanced technologies and systems that can improve urban highway traffic operations by achieving significant increases in capacity and traffic flow; and
2) for the most promising of these technologies and systems, formulate a plan for research, development, testing and demonstration.

The Phase I (9 months) task plan calls for attention to be given to identifying topics such as automated vehicle control, in-vehicular route guidance, improved motorist communication, and automotive vehicle identification that offer significant promise of improving urban highway traffic operations. Each identified technology is to be assessed in terms of potential benefits, costs, institutional issues, public/private sector roles, funding mechanisms, etc.

Phase II (15 months) will include detailed assessments of a maximum of three technologies selected on the basis of the

EXHIBIT 35

MOTOR CARRIER INDUSTRY MARKET SEGMENTS

	SERVICE AREA	ROUTE TYPE	FIRM TYPE	HEAVY TRUCKS
			For-hire, Special Commodity, Class II/III	280,000
			For-hire, General Freight, Class II/III	110,000
		VARIABLE ROUTES 615,000	For-hire, Special Commodity, Class I	110,000
			Private, Special Commodity Fleet, Medium/Small	115,000
	NATIONAL, REGIONAL, INTRASTATE OPERATIONS (beyond two-way radio, cellular telephone range) 1,110,000		Private, General Freight Fleet, Large	70,000
		MIXED ROUTES 280,000	For-hire, General Freight, Class I	210,000
			Private, Special Commodity Fleet, Large	50,000
		FIXED ROUTES* 215,000	Private, General Freight Fleet, Medium/Small	165,000
HEAVY TRUCKS (>26,000 lbs GVW) 1,919,000				
			For-hire, General Freight, Class II/III	45,000
		VARIABLE ROUTES 117,000	For-hire, Special Commodity, Class I/II/III	72,000
			Private, General Freight/Special Commodity Fleet, Medium/Small	485,000
	LOCAL OPERATIONS (within range of two-way radio, cellular telephone) 809,000	MIXED ROUTES 487,000	For-hire, General Freight, Class I	2,000
			Private, Special Commodity Fleet, Large	95,000
		FIXED ROUTES* 205,000	Private, General Freight Fleet, Large	110,000
			TOTAL:	1,919,000

* Predominately Fixed Routes, some Variable

Source: Arthur D. Little, Inc. Estimates

Phase I results. In addition to a more detailed analysis of the factors covered in Phase I, Phase II will examine such issues as environmental considerations, social impacts, developmental risks and implementation risks. The final results of the project will be a detailed RD&D program plan for each of the three selected technologies, describing the next stage of research, planning and program development.

5.3.8 CALTRANS/FHWA/Industry Experiment

Due largely to the catalytic effect of the CALTRANS Conference on "Technology Options for Highway Transportation Operations", held in Sacramento, California, 28-31 October 1986 (Ref 79), a coalition - including the FHWA, CALTRANS and private industry - developed a plan for an experiment to evaluate and demonstrate the traffic management advantages of providing real-time traffic information to on-board navigation systems. This plan is expected to lead to an initial procurement action by the FHWA in late 1988 to select a systems integrator for the demonstration to be carried out in 1989-90.

The two major objectives of the experiment are to investigate the effectiveness of:

* real-time traffic information in conjunction with an in-vehicle navigation system as an aid in coping with traffic congestion
* the use of "floating" vehicles as a means of obtaining information on current traffic conditions.

The real-time traffic information will give the driver a basis for choosing faster moving routes and the navigation system will aid the driver in following alternative, hence, less familiar routes. The "floating" vehicle concept takes advantage of the tracking ability of the in-vehicle navigation to acquire time and motion data which will be periodically transmitted to the traffic information center to provide additional details on traffic flow.

The approach and preliminary plan for the experiment assume use of the Etak Navigator™, the only automobile navigation system already available in the U.S. The Etak system is based on dead reckoning augmented by map matcning, and the vehic-

le's location relative to its surroundings is continuously displayed on a monochrome CRT map presentation which may be zoomed to different scales as described in Section 2.1.5.

While the Etak system does not provide route guidance per se, software modifications would permit the system to superimpose real-time traffic data on the map display in a manner such that the driver could take it into account in route planning. Traffic data collected by various means will be communicated to Etak-equipped vehicles via cellular data phone; these will also be used to communicate recent travel experience of Etak-equipped vehicles to the traffic centre for additional information on current traffic conditions. Approximately 25 test vehicles (provided by GM) will be used in the experiment. Because this number of test vehicles will not generate statistically significant results, controlled tests will be conducted. Pairs of vehicles, one equipped and one unequipped, will be simultaneously dispatched to the same destinations to measure differences in travel time and distance.

The present plan is to include the experiment in the already-formulated SMART Corridor Demonstration Project in Los Angeles. This project is located along the Santa Monica Freeway Corridor between Soto Street east of downtown Los Angeles and the San Diego Freeway. The freeway flow management system will be linked to a new system of street signal management on Olympic, Pico, Venice, Washington and Adams Boulevards.

5.3.9 FHWA Futures Study

The study was originated April 1987 to project demands on the highway system in the 2000-2020 time frame. Nineteen working groups addressed tasks such as "impact of telecommunications and computers on highway travel" and "advances in instrumentation, vehicle and traffic control technology". The tasks will be consolidated into four categories: demographics, economics and travel demand / technological advancement / highway systems analysis / federal policy. There is special emphasis on in-vehicle route guidance and adaptive control.

A final report, expected in two years, will suggest direction and roles for the FHWA; as one official puts it "We're prepa-

ring for the next Highway Act." Publication of issue papers will be an important mechanism for dissemination of findings.

5.3.10 Recent Developments

There are several new initiatives in North America involving mobile information systems which are of interest:

Program for Advanced Technology for the Highway (PATH) - Institute of Transportation Studies (Univ of California) is assisting the California DOT (CALTRANS) in conducting a program of advanced R&D to reduce congestion. The focus will be on three independent but related technologies: navigation, electrification and automation.

Intelligent Vehicle-Highway System (IVHS) - Transportation Research Institute (Univ of Michigan), has began a study which seeks to improve the efficiency of highway travel by enhancing the support of driver functions with intelligent aids. This research - supported by automobile electronics and other companies, Motor Vehicle Manufacturers' Association, American Automobile Association, Federal Highway Administration, National Highway Traffic Safety Administration and Transport Canada, covers technologies from navigation and route guidance to the automatic highway for the next century.

Texas Advanced Transportation Technology Project (TexATT) - This project, initiated by Texas Transportation Institute (Texas A&M University) to reduce congestion by the application of advanced technology to highway transportation, will proceed in three stages (planning->environmental study->technical study) and will be complementary to ongoing studies in California and Michigan.

Mobility-2000 - A committee composed of representatives from FHWA, NHTSA, California, Michigan, Massachusetts, Minnesota, MVMA and others was established to coordinate the various IVHS studies underway in the U.S.

Advanced Driver Information System (ADIS) - Initiated by FHWA to develop a national concensus on the functions and configuration of a future in-vehicle driver information systems.

Vehicle Navigation Information Systems Conference (VNIS'89) - The conference covering all aspects of mobile information systems technology and application will be held in Toronto 12-14 September 1989. It is sponsored by IEEE Vehicular Technology Society, IEEE Toronto Section, Ministry of Transportation of Ontario, and Transport Canada.

6. STANDARDS & REGULATIONS

6.1 INTRODUCTION

6.1.1 Areas of Coverage

There are several broad areas for which design guidelines, recommended practices, defacto or official standards, and specific regulations will need to be developed, before wide scale adaptation and use of mobile information systems. The primary focus will have to be on ensuring safety and reliability, which is not an easy task considering the range of capabilities expected from these in-vehicle devices in the future: positioning, navigation, interactive route guidance, information management (mobile office functions), communications between the vehicle and other vehicles, roadside, operations centres, and satellites, and vehicular monitoring and control.

To ensure safety in use - and compatibility between in-vehicle systems themselves, between the systems and the 'outside' (external communications) - recommended practices and standards will need to cover:

* map data bases
  - mapping and compilation specifications for digitized maps: scales, coding schemes and file formats
  - transfer techniques and formats for digital map data interchange
  - on-board map database: primary topological data storage structures (combinatorial topology, ...) but with flexibility for including [a full/very limited] range of geographic information system (GIS) features
* CD-ROM formatting, eg. using Yellow Book Mode 1 + High Sierra or Green Book with map data and programs stored via Form 1 using High Sierra
* map data base access software: handles (pointers needed by the underlying software but not by the application) and the call-and-return interface between the underlying and the applications software

* applications software (display, navigation, routing, information management, etc) - but only to secure basic consistency in manner by which:
  - function keys or touch screens are laid out, eg: maximum number of functions per screen by size
  - icons and colours are chosen
  - streets are labelled
  - some critical features are displayed, eg:
    - one-way streets, and reversible streets/lanes
    - HOV lanes, ramps and parking
    - routes designated for trucks, hazardous goods, emergency vehicles and snow removal
    - parking restrictions & loading/unloading zones, and
  - overall graphics standard, eg: Programmer's Hierarchical Interactive Graphics Standard (PHIGS)
* on-board equipment specifications
  - hardware & system software primary characteristics (note however: in many cases, the details of the standards will depend on the particular technology that is chosen for the hardware systems)
  - compatibility with vehicle computers (engine diagnostics, etc): communication protocols & LAN standards (application, presentation, session, transport, network, data link, physical)
  - map displays: vector, digitized raster graphics, ... min visibility in direct sun light, ...
  - navigational systems: sensors and processors
  - boot procedures (so that systems based on different processor families can each look up their object code and boot from it)
  - ROM based basic input/output system (BIOS) that includes all hardware dependent input and output: sensor input, mass storage access and display output
  - removeable mass storage formatting
* manner of installation and mounting (& design of the casing and controls)
  - integrity of passenger compartment safety
  - angles and distances from the driver (coupled with passenger presence via seat sensor), ie:
    - when to assume that the device is being used by a passenger only - therefore allowing more features to operate even when vehicle is in motion
    - when to automatically suppress features (when in-motion)

* preferred practices (or standards) on all transmissions into the vehicles, eg. information overlays transmitted from:
  - traffic management centres - manner (ie. tone of statement, abbreviations and colours used, etc) in which:
    - congestion levels are displayed and expressed
    - advise on preferred routes is given
    - incidents are categorized
    - access control and user prices are applied and charged
    - etc
  - community broadcast centres, concerning:
    - road & weather conditions
    - emergency messages
    - road side services
    - community marketing
  - EDI (electronic data interchange) standards: application level syntax rules (EDIFACT) for the automotive industry (under consideration by EDI Council of Canada's Automotive Industry Action Group (AIAG))
* all traffic control devices, including lane markings, which may be designed to transmit a location or control/rules message (MUTCD and Canadian Pavement Marking Standards)
* communications - frequency allocation
  - communications protocols
* human factors: man-machine input and output interfaces between the operator (most often the driver) and the on-board equipment.

6.1.2 Issues in Standards Development

The guidelines, recommended practices (RP) and standards in these areas must be uniformly applied to all vehicle types. The debacle of light trucks, vans and minivans not having to meet the Federal Motor Vehicle Safety Standards (FMVSS) - because they are classified as Multipurpose Passenger Vehicles (MPVs) - must not be repeated (note that H.R.1211, introduced 24Feb87, would change this in the U.S.). Both the devices, and the manner in which they can be installed and used, must be consistent across vehicle types.

Finally, there will need to be standards related to quality control in the manufacturing and after-market installation of these devices - particularly, where vehicle monitoring/control systems are involved. The number of recent automotive recalls, related to serious electronic systems failures, well illustrates this requirement, eg: sudden surges without pressing (or even touching) the accelerator; electrical front seats suddenly heading backward (in the middle of driving, without the controls having been touched); etc.

However, it should also be noted that regulations - or more particularly, the sometimes suffocatingly slow regulatory processes - can quickly stifle innovation and development attempts where it can hurt progress most - at the small entrepreneur level. It will probably be desirable to establish interim guidelines, however imperfect, rather than hold everybody (and particularly those that got a marketable idea first) back indefinitely while the 'ultimate, perfect, all-encompassing' regulations are tediously developed in colossal tri-party committees (all the while giving generous time to the less innovative companies to catch up).

An example of a somewhat similar situation is the delay (at least two years) expected in Europe with next generation cordless telephones - if Time Division Multiple Access (TDMA) standard is to be adhered to, compared to the existing Frequency Division Multiple Access (FDMA) standard for which the technology is essentially ready now.

> "The standards-developing process is lengthy and arduous. It begins with identifying a need for a standard, and it ends with its implementation. In between, there is a long series of meetings, discussions, preparation of drafts, reviews, rewrites, and sometimes, repetitions of the total process." (SAE UPdate, 15 April 1988)

A second challenge relating to standards is how to publicize them. A recent survey on Open Systems Interconnect (OSI) in U.K. found that only 25% of local authorities in the country were aware of the European Commission's directive (International Standards Organization standards, including ISO/OSI, must be specified in procurement).

The standards/regulations making government bodies need to know a lot about what the industry is doing, or about to do,

so that they can more effectively spend their own research dollars, and ultimately recognize when and what rule making might be appropriate.

The initial focus in this task has been on two areas:

- discussion on map standards (Section 6.2)
- preliminary guidelines for human factors (Section 6.3).

6.2 MAP STANDARDS

Increasing amounts of map data are being digitized, exchanged, stored, retrieved, etc. The basic elements associated with map data (points, lines, polygons, grid cells, pixels, etc.) are being used for geographic analysis and network analysis as well as map making. Little coordination exists among the methods by which vector/raster, cartographic/imagery data are geographically referenced to the surface of the earth. In addition, little coordination exists in expressing the parameters and reference systems in use.

The concerns for common data formats and geocoding conventions cut across all sub-fields and topics of computerized cartography and digital map utilization. Hence, there are standardization efforts underway for the broader aspects of digital maps as well as for the specific digital maps required for car navigation and route guidance.

6.2.1 United States

Operating under the auspices of the American Congress on Surveying and Mapping, the National Committee for Digital Cartographic Data Standards (NCDCDS) is working to establish broad standards generally applicable to all digital mapping. The National Committee was formed in 1982 and defined its primary goal as follows:

> 'To provide a professional forum for all involved Federal, State, and local public agencies, private industry, and professional individuals to express their opinions, assessments, and proposals concerning digital cartographic data standards. After sufficient time for the formulation, circulation, discussion, reformulation and comment, these proposed standards will be submitted to the

U.S. Bureau of Standards to become national digital cartographic data standards.'

A Steering Committee and four Working Groups were organized and have been in full operation since 1982. Several reports, including an interim proposed standard, have been issued by the Committee:

* Defining the Issues (1983)
* Examining the Alternatives (1984)
* A Working Bibliography for Digital Cartographic Standards (1984)
* An Interim Proposed Standard (1985)
* A Report on Evaluation and Empirical Testing (1986).

The interim proposed standard (Ref 60), which was issued early in 1985, was the subject of special public hearings at the AUTO-CARTO 7 Symposium in conjunction with the Annual Convention of the American Society of Photogrammetry and the American Congress on Surveying & Mapping in Washington, D.C. on 11-14 March 1985. Written comments and opinions were also solicited.

Draft proposed standards were issued in January 1987. Special hearings on the draft standard were held at the AUTO-CARTO 8 Symposium scheduled for 30 March - 2 April 1987 in conjunction with the American Society of Photogrammetry and the American Congress on Surveying and Mapping Annual Convention in Baltimore, Maryland. After melding with the work of the Standards Working Group of the Federal Interagency Coordinating Committee on Digital Cartography, the draft standard was published for public review in January 1988 issue of the American Cartographer (a journal of the American Cartographic Association of the ACSM).

The Society of Automotive Engineers (SAE) has formed a 'Subcommittee on Automotive Navigational Aids' whose objectives include establishing digital map standards addressing the specific additional requirements of automotive navigation.

6.2.2 Canada

The following presents a point form summary on map standards related activities of agencies at three levels of government - federal, provincial and municipal:

Energy, Mines and Resources Canada (Topographical Survey Division / Surveys & Mapping Branch / Earth Science)

* conventional specifications for structuring non-relational 'spaghetti' data are ready; digital specifications are coming shortly
* Topographic Mapping Manual of Digital Compilation Specifications and Instructions published in 1986
* uses ISIF, the Intergraph Standard Interchange Format coding scheme and file format (Metro's scheme is also ISIF, but the feature codes are different, ie. correlation tables are needed between the two)
* for digital data exchange, EMR subscribes to the Canadian Council of Surveys & Mapping transfer format (from 1976); this was designed for transfers using tape (or CD-ROM, etc carry-on method), whereas MNR's MDIF is designed for data exchange via telephone lines, satellite, ...

Ministry of Natural Resources / Ontario (Surveys, Mapping and Remote Sensing Branch)

* is developing a telecommunications oriented interchange format, called 'Map and Chart Data Interchange Format' (MACDIF)
* Map Data Interchange Format (MDIF) standards, which are a subset of MACDIF, have been completed (15 June 1987)
  - no other (Ontario) ministry is yet participating in this development
* MNR uses ARC/INFO to generate its data base (same that ETAK uses)
  - once MDIF is completed, there will be an ARC/INFO-to-MDIF soft key (as there is one for ETAK)
  - there is still a need to develop:
    - an ISIF-MDIF interface
    - standards summary in a layman's matrix format

* MDIF demonstration is planned for Summer 88:
  - to transmit a full map sheet from Toronto to Ottawa via telecommunication lines and reconstruct (with a micro-computer) the map at the other end
  - subsequent tests will demonstrate transmission to a dummy terminal for automatic display
* the federal government (Canadian Hydrographic Service) is using MDIF document as a base for displaying maritime charts on simple display terminals on ships
* comments on ISIF
  - does not allow transmitting topology, ie. spacial relationships, therefore a key capability is missing
  - is designed for carry-on transfer, eg. magnetic tape, CD-ROM, etc - while these can also be transferred via communication lines, their format is not compact enough to do it efficiently.

The Municipality of Metropolitan Toronto (Central Mapping Agency)

* Digital mapping specifications have been developed:
  - 1981 original & February 1984 revised
  - 1988 updates: file structure same, but data + accuracy of capture different
* CMAL, the permanent feature code, will not yet be included; it will eventually be similar, via a cross-reference table, to EMR's feature code
* data exchange between systems
  - ISIF and Synercom (but ARC/INFO link to ISIF not yet prepared); not compatible with MNR's MDIF
  - MDIF originally deemed necessary (by MNR) for transfer of precision locations to ships and aircraft at the shortest possible transmission time (transfer over phone lines) - a requirement, that is not a priority within Metro
  - Central Mapping Agency not entirely clear on the intended requirements and uses of MDIF
* Metro's CMA will supply all of Metro to ambulance, police and fire departments as a geographic digitized reference system containing: topography + streets + address range for each postal code block.

The development of standards for (digitized) marine cartography is also underway in Canada and elsewhere. This is

likely to have an impact on some of the standards and data interchange formats being developed for the ground side. A brief summary of the federal activities in this area is presented in Appendix F.

6.2.3 Others

Groups in Europe and Japan are working toward the establishment of digital map standards for automotive navigation. The most notable achievement to date is the development of a draft standard for a Geographical Data File (GDF) exchange format by the EUREKA project DEMETER (Ref 22). DEMETER is outlined in Section 5.1.6.

6.3 HUMAN FACTORS

6.3.1 Introduction

There is a definite need to establish design guidelines, recommended practices, and standards, that would be based on sound research, *before* the new sophisticated mobile information systems are in wide use in automobiles. Very little reliable information is available at the present time. Simmonds (Ref 120) warns that there is a considerable amount of technical literature in the area of electronic instrumentation, most of recent origin, but very little is reliable and often the recommendations are based on the authors' opinions or on small scale testing.

> An example of what this can lead into is revealed by a recent luxury vehicle test article: "The instrument panel is dominated by the touch screen that makes you think a computer hacker crept into the interior-design studio. The screen replaces 90 conventional switches and incorporates most of the comfort and convenience controls, including the climate control system and the radio, *and manages to make them inconvenient to use particularly when driving*."
> (Dan McCosh, Detroit Editor/Popular Science, April 1988)

The International Standards Organization (ISO) has set many standards which could serve as a basic guideline to the designer when developing a display. Henry Dreyfuss Associates (Ref 110) have developed a system of design guidelines and

standards known as "Humanscale", and these too may be of some value in the standardization of automotive features.

At present, it may be necessary to introduce some "stop gap" guidelines in order to prevent possibly harmful designs from being introduced without the benefit of having any legitimate research results available.

6.3.2 Preliminary Design Guidelines

The following preliminary suggestions for mobile information system design guidelines are based upon research (most of which has been highlighted in Chapter 3 and Appendix C) and literature reviews that have been recently performed:

1) At the present only the speedometer, odometer, gas gauge, possibly a tachometer and a limited number of status and/or warning lights (gauges) should be allowed in the vehicle. This is to say, for the time being, we should maintain the status quo.[1]

2) If a vehicle manufacturer (or an after-market supplier) wants to introduce additional displays and controls, he must be able to demonstrate - using acceptable human factors experimental techniques, representative driver samples and vehicle operating circumstances - that this new device is not dangerous in terms of distraction, time spent to operate, frequency of use, lateral standard deviation of the vehicle, etc.[2]

3) A manufacturer should be required to demonstrate that while a driver is using the device, the probability of the driver laterally exceeding a straight and level driving lane is less than a selected percentage value based upon a 3.5 m lane width and a driving speed of X km/h.[2]

4) It should not be possible for the driver to use either the controls or the displays of mobile information systems just prior to entering a curve or on a curved sections of a roadway due to the increased visual and steering demands placed upon the driver.

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1) It is acknowledged that today's status quo includes a radio; which, however, for road safety reasons would then have to be exceedingly easy to operate. The same applies to any climate controls. In both cases, the primary tuning would desirably take place when the vehicle is stationary.

2) Standardized evaluation criteria, that would provide a common, stringent basis for comparing the effects on road safety of new in-vehicle devices and modes of their operation, are not yet fully developed and agreed upon by the automobile and navigation industries, academia and the regulators.

Whenever the vehicle is in motion, the display content - if in use by the driver - should be drastically simplified; ie. possibly no map display (instead, simple turn indicators only), or a skeleton road network at the most.

No display which requires more than three eye fixations of maximum 0.6s each, or a total of 1.8s, to obtain all needed information should be put into a vehicle. (2

All controls and displays of a mobile information system could be fully operable for a front seat passenger if he/she is clearly the sole user, ie. as long as the device is angled correctly (away from the driver's field of vision), and the passenger's presence is confirmed by an in-seat sensor. All MIS functions could also be operable whenever the components-in-use are located behind the driver's seat (operated by a rear seat passenger).

5) Only very limited in-vehicle visual information should be provided to the driver under adverse driving conditions such as night driving, inclement weather conditions and during heavy traffic situations.

   However, the passengers ought to be able to operate all controls and view all visual information (when there is no concurrent use by the driver).

6) All controls and displays should appear within 30 degrees of the driver's visual arc since only a limited amount of information can be obtained by a driver, without significant head movement, when information is displayed in the periphery of his/her visual field. (3

7) All systems should be designed to be adjustable such that they are equally safely usable by all drivers from a 95th percentile male to a 5th percentile female.

8) A digital presentation of a numeric value is preferable when precise values are required.

9) 15 minutes of visual arc is the minimum subtended angle for alphanumerics recommended for use in electronic displays. Two to three times larger than minimum numeral and character heights are preferable.

10) A minimum foreground to background luminance ratio of 3:1 should be required (7:1 preferred) by all displays (ANSI Standard for VDTs, 1986) and the luminance should be adjustable in the range from 500 to 60 000 lux. Also, the luminance variation across normally used portions of

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3) Note that further research in the areas of cognitive capture, elderly drivers, etc is required to resolve the application of this guideline, particularly as it relates to the amount of information being displayed and to HUD devices in general. This is true for many of the guideline elements (see Section 7.2.3 for a recommended research program).

the display should be limited to a maximum of 50%. [Ref: Farrell & Booth (1975) and ANSI Standards for VDTs].

11) Alphanumeric messages should have characters with a stroke width of 1:8 and a minimum width to height ratio of 1:1 (1:0.9 is preferable based on ANSI Standards for VDTs). The size of a symbol should not vary by more than 10% regardless of its location in the image area (ANSI Standard for VDTs).

12) ISO Standard 2575 should be followed for the use of colours for status and warning lights.

13) Displays which use red-green or yellow-blue should not be used so that colour deficient users will not confuse pertinent information.

14) CRTs are not to be placed more than 30 degrees outside the driver visual field in order to avoid problems caused by the flicker of the display. Flicker must be avoided.

15) Auditory signals which use frequencies below 200 Hz or above 3000 Hz should not be used so that the highest percentage of drivers will be able to detect the signal; for incoming calls, a sound pressure limiter with a cut-off at 90 decibels should be used to prevent the driver being startled in the middle of driving.

16) A maximum transmission rate of 250 words per minute is recommended when a speech presentation mode of information presentation is selected for use.

17) Auditory messages or signals cannot solely be used to present vital information since it cannot be assumed that the driver has full hearing capabilities.

These examples of (preliminary) design guidelines are by no means exhaustive. Extensive research is still required and follow-up recommended practices and regulations will need to be developed with regards to the standardization of the:
(see also p.155-157)

- placement of the display and control devices
- types of control devices and methods of control
- different display technologies.

Until the safety of a device has been sufficiently proven, the use of the device should be restricted.

7. RESEARCH, DEVELOPMENT AND DEMONSTRATION NEEDS

7.1 INTRODUCTION

7.1.1 Focus Beyond Phases I and II

Research, development and demonstration needs in the area of mobile information systems are very broad, as can be seen in:

- Exhibit 19: Electronic Display Design Guide (Section 3.4/p.91).
- Exhibit 27: Future Mobile Information Systems - A Functional Block Diagram (Section 4.3/p.111)

This study - Mobile Information Systems Impact Study / Phase I & II - has focused exclusively on determining the state-of-the-art of those in-vehicle devices which can display the vehicle's position (relative to a map base) within the vehicle itself, and facilitate/perform on-board navigation and route guidance.

Systems that 'only' provide automatic monitoring, at a remote site (eg. dispatch centre), of the location and performance of a fleet of vehicles have not been covered by Phase I&II of the study. Neither have the basic on-board vehicle electronic systems (for engine, drive line, etc monitoring and control), nor recent developments in radars, driver performance/condition monitoring, etc been covered (for a list, see Exhibit 28/p.120-121). Phase I&II did also not focus on the state-of-the-art of a broad range of travel support systems.

These systems, and the manner in which they are incorporated into the primary vehicle navigation/information unit, will have a critical impact on what the overall system capabilities will be in the future, how these systems function (internally) and how they are operated - and, particularly, what the rate of market penetration will be. It is therefore recommended that a follow-up study be undertaken as soon as possible. This is introduced as the priority project amongst recommended projects presented in Section 7.2.

7.1.2 Other Research Needs

In order to accelerate the development and manufacturing of these systems in Canada - and to support the development of recommended practices and standards (Section 6.1.1) - research, development and demonstration work will need to undertaken in the following areas:

* map data bases (permanent vs. updatable) and related access software
* applications software
  - application specific
  - individualized (user specific)
* on-board equipment specs (fail safe / fault tolerant)
  - navigation/other sensors & actuators
  - microprocessors & system software
  - data storage devices
  - input/output devices
* manner of installation and mounting
  - to secure passenger compartment safety
  - to position/align for use by: driver vs. passenger
* design/transmission of
  - information overlays
  - data base updates
* traffic control devices which can transmit/receive/sense
* communications
  - fault tolerant LAN within the vehicle
  - vehicle to/from
    - other vehicles
    - road side systems
    - operations centres
    - satellites
* human factors.

The development of mobile information system displays and controls is a complex man-machine interface (MMI) design issue (see Exhibit 19) and requires therefore very delicate system trade-offs. The most critical 'trade-off' will be [safety vs. performance]; and it must be asked whether we can afford to trade off any safety at all? In any case, there is no adequate data available yet to make thorough trade-off analysis possible.

In the Canadian context, some of the above areas could particularly benefit from participation by federal, provincial and municipal government agencies. Six research areas, some of which incorporate several of the above primary topics, are

outlined in the following (Projects 7.2.2 - 7.2.7). Note that the human factors area (7.2.3), due to its scope, would need to be divided into several separate studies/investigations.

The sequence of projects 2-7 does not imply priority.

7.2 RECOMMENDED R&D PROJECTS

7.2.1 Highway Vehicle Electronics Project

Objective: to complete the state-of-the-art review for highway vehicle electronic technologies not covered under in-vehicle navigation and route guidance systems (focus of Phase I&II of this project).

Tasks

* review and present background / state-of-the-art / potential applications / markets & suppliers / government roles for:
  - automatic (remote) fleet monitoring systems (AVI, AVC, AVL, AVM) and for weigh-in-motion systems (WIM)
  - vehicular monitoring and control systems: vehicle systems status, data acquisition, vehicle position (vs. other vehicles & obstacles), driver condition and performance, etc
  - travel support systems: on-board and remote data bases, systems for mobile office and occupant activities
* review human factors considerations for the above highway vehicle electronics systems.

7.2.2 Demonstration Project

Objective: to gather operational experience with an in-vehicle navigation/mobile communication system in a metropolitan operating environment.

Tasks

* select a few complementary functions/features (review Exhibits 27 and 21-26) which would illustrate a marketable package of capabilities; decide whether the system is intended for:
  - passenger or freight vehicles;

- commercial, business or private use; and
- what features can be quickly provided through an on-board GIS or external (accessible) data bases
- etc

* select a commercially available autonomous navigation system, cellular radio, intelligent modem, lap-top computer, fax-machine and/or any other hardware required to provide the selected functions

* identify an urban area, or a section of a metropolitan area, in which:
  - a map data base is readily available (requiring minor or no work, except conversion to the navigation device format) [note that the area must also be suitable for proper demonstration of the advantages/limitations of the selected features]
  - other support systems can be readily provided (eg: independent monitoring of vehicle's location, traffic and weather information, tie-in to external data sources, ...)

* undertake the demonstration
  - identify a user willing to participate, ie. to install the device in his/her vehicle, use it constantly, provide statistics on before/after performance, etc (design an installation test bed that will closely simulate likely ultimate positioning of the components)
  - design system software, and applications software, to demonstrate general safety, ease-of-use and effectiveness of the selected application features
  - monitor use; modify applications software as required to ensure safety & effectiveness in use; document results.

7.2.3 Human Factors Studies

Objective: to investigate all critical man-machine-interface issues related to the design, installation and use of mobile information systems - so that these devices will not degrade but enhance the overall safety of the driver-vehicle system.

(Ref: Electronic Display Design Guide: Exhibit 19 / Section 3.4/p.91)

Studies/Tasks

Note that all studies/investigations/tasks outlined below would distinguish between different user categories - such as age group, condition of the driver, etc - where this is likely to affect the safety-in-use or the general performance of the mobile information system.

* determine the amount of information that may be (safely) presented to the driver when his/her vehicle is moving, depending on:
  - whether the driver is in a familiar or unfamiliar area
  - what the traffic and weather conditions are
  - what the road geometry and surface conditions are
  - what the driver's condition is (eg: from rested/alert/unhurried to tired/agitated/rushed)
* determine the effect that sophisticated mobile information system controls and displays have on driver's attention, perception, reaction time, lateral lane position, speed maintenance and compliance with traffic control devices; and
  - assess how:
    - to best parcel/sequence information (ie: into the required elements of a route instruction, etc)
    - long to display each element and when (in relation to decision points)
    - much redundancy is desirable (in view of the differing road network and other knowledge of users)
  - assess the difference between having numerous in-vehicle devices (for various purposes) vs. combining all functional capabilities into one (navigation) master unit with one set of input/output devices
* expand the driver eye scanning data base, to determine:
  - fixation duration and accommodation times both in the foveal plane and in the periphery
  - the amount of time required to gather location and other information from such displays as maps, alphanumeric and representational displays - under both ideal and adverse conditions
  - differences caused by different display technologies: CRT, LED, LCD, vacuum fluorescent, HUD, etc
* investigate ways of reducing the driver's visual load inside the vehicle, by such means as:
  - synthesized speech, speech recognition mode, HUD technology, etc

- driver warning and assistance devices: gap alerts, collision avoidance systems and in-vehicle radar
- simplified illustrations of road corridor or network data (eg: to display a skeleton road system and/or expected turns only)
  - and what is the minimum data required to ease finding a desired route or destination (and the incremental benefits from more extensive information)
- software shells for high degree of individualization and simplification in use of controls
- making the device installation such that independent use by passengers (front & rear seat) is made possible

* determine minimum desirable graphics processing speeds and replenishing rates; evaluate alternative command approaches/languages, entry methods, interfaces, etc
  - determine what is the "best" graphics, the "best" font, the "best" display mode and technology
  - determine what are the "best" controls and command sequences
  - tailor to the lower tail in driver population; users do <u>not</u> typically have perfect vision, hearing, muscular control, attention span, quickness of mind, etc; (and their mental state can range from rested/alert/unhurried to tired/agitated/rushed)
* assess the possibility of developing models which can be used to quantitatively predict the impact of mobile information systems on driver performance and safety; and
  - validate the model capabilities in typical driving situations in the field
  - assess how much are driver performance and transportation efficiency/safety actually increased.
* develop standardized evaluation methodology and criteria, that will provide a common, stringent basis for comparing the effects on road safety of new in-vehicle devices and modes of their operation; and
  - consult with automobile and component manufacturers, mobile information system component developers, university research community and the regulators in order to seek advice and a consensus on the fundamentals of road safety related evaluation of these systems.

7.2.4 Market Survey

Objective: undertake a mail/telephone survey of associations, and some of their prominent members, representing potential users of mobile information systems & undertake personal interviews of a small group of individual users.

* refine interview guide (Appendix E) into a self-coding form that can be used in a mail-out survey
* undertake survey of potential direct, indirect and intermediary users, to:
  - gauge current knowledge, system expectations and future intentions of individual users
  - segment the market into user communities, with similar needs and priorities
  - identify general, unique and mixed applications and likely priority functions (for 'function keys')
* undertake complementary segment analysis
  - develop cross-tabulations of latest vehicle registration and sales data (dividing the vehicle population into categories that imply probabilities of equipment installation)
  - undertake a brief operational review (trip purpose/mission analysis, ...) at a dozen likely major fleet users of the systems
* undertake a personal interview survey of drivers/passengers to learn about current techniques of finding the most direct/scenic/non-congested/etc routes to various destinations (pre-trip and en-route techniques).

7.2.5 Supplier Survey

Objective: undertake a mail/telephone survey of current and potential Canadian suppliers of mobile information systems hardware and software components.

* refine the list of potential suppliers
* review the list of respondents and the results of closely related surveys (avoid needless duplication)
* develop a self-coding form that can be used in a mail-out survey (design the form also as a marketing tool to generate interest, by the target audience, in mobile information systems)

* undertake survey of research facilities and current/potential hardware and software suppliers, to
  - learn about current research, development, concept design, design and production work on mobile information systems or closely related technologies
  - learn about current/potential suppliers' future intentions in the same area
  - learn about companies' views on who the customers of their products/planned products are (determine what the suppliers think the market needs are).

7.2.6 Information Dissemination Project

Objective: inform potential users, suppliers and regulators of mobile information systems, about the state-of-the-art of emerging technologies and of possible applications to which these systems may be adapted.

Tasks

* establish a bi-annual newsletter dedicated to mobile information systems (guided by a federal/provincial/municipal editorial board)
  and/or write and assemble small briefing notes to trans mit to editors of user & supplier associations' publications and other news letters
* arrange presentations at specialist and non-specialist conferences and annual meetings; approach universities' program managers to discuss the emerging developments
* present highlights of MIS technology, including its potential applications, to municipal/provincial/federal transportation agencies, traffic managers and operators of emergency services
* arrange a major international conference/trade show: the Vehicle Navigation and Information Systems Conference (VNIS'89) has now been scheduled for 12-14 September 1989; expand the (original scope of the) marketing effort to include extensive publicity with potential Canadian suppliers.

7.2.7 National Strategy Project

Objective: to develop a national strategy for advancing research, development, demonstration, manufacturing and application of mobile information systems in Canada.

Tasks

* designate coordinator & establish a small working group of representatives from agencies with primary interests in mobile information and related systems
* review multi-national and national programs from Europe, Japan and the United States
  - overview presentation to steering committee: establish primary questions/concerns for follow-up visits to program sites
  - periodic updates: establish a monitoring project to keep hands-on current on themes, specific objectives, program elements and demonstration projects
  - identify opportunities for Canadian participation in the various R&D&D projects underway in Europe, Japan and the United States
* review results of Canadian projects (as they become available)
  - highway vehicle electronics project
  - small scale demonstration(s)
  - human factors investigations
  - market (user) and developer/supplier surveys
  - feedback from information dissemination
  - other related Canadian projects
* develop stop gap rules and recommended practices
  - refine the preliminary design guidelines developed for mobile information systems (Section 6.3.2)
  - identify additional areas requiring standards; consult with MIS equipment suppliers, vehicle manufacturers, human factors researchers and regulatory agencies
  - coordinate/monitor subsequent development of regulations at research facilities and government agencies
* develop a system configuration and specify primary functional capabilities of an advanced in-vehicle positioning/navigation/route guidance/information system (which would best advance the safety and efficiency of roadway transportation in Canada)

* identify further R&D&D needs and short term funding requirements to effectively start the exploitation of MIS technologies; and
  identify potential industry/university/government research organizations and groups for undertaking the work
* develop and further specify options for a short/medium/long term Canadian technology strategy, including:
  - do nothing (ie. no government-funded participation beyond current work)
  - low level monitoring (reviews of published literature)
  - periodic state-of-the-art reviews
    - extensive literature reviews
    - participation in relevant international committees and TRB/SAE/etc annual meetings
    - visits to demonstration sites
  - an industry/university/government collaborative R&D&D program (ie. 'Canadian Prometheus')
* identify likely economic and other benefits and costs from following each of the strategies
* identify preferred strategy & outline primary work areas & identify funding needs.

7.3 CONCLUSION

Recently there has been a great deal of renewed interest in in-vehicle systems that would provide a range of positioning, navigation, route guidance, vehicle systems/driver monitoring, mobile information management and communication capabilities. This has been boosted by developments in micro-electronics, particularly in data storage and display technologies - and almost equally, by the emergence of grid-locked traffic conditions and increased accident rates in major metropolitan areas.

Several rudimentary on-board units are already, or are about to become commercially available; and major international and national programs have been established in Europe and Japan. The United States is beginning to follow suit at both national and state levels through several advanced technology research and demonstration projects.

This is in strict contrast to Canada, where no formal national strategy for advancing the research, development, demon-

stration, manufacturing and adaptation of mobile information systems technology has yet been formulated. No Canadian designed units exist - and, it seems, none are yet contemplated. For the Canadian automotive and electronics sectors and university research facilities, such complacency, if continued, will result in forgoing some unique industrial development and marketing opportunities.

There are many unanswered questions which require research, development and demonstration work in the Canadian context. It is unclear at this point which technology, if any, will come on top: autonomous dead-reckoning supplemented with map matching, or navigation systems based on proximity devices, ground based radio signals or satellites.

Only very limited market surveys have been done, therefore it is not known what package of hardware components would be the most cost-effective and responsive to real user needs. An equally great challenge will be to identify and develop applications software that makes the wide range of functions, which are required in order for these systems to be widely adopted, easy to use.

Increasing transportation safety and efficiency will have to be the two primary considerations in the development of mobile information systems. While preliminary design guidelines for the man-machine interface aspects are presented in this report, much work is yet to be done on the design, installation and use of these systems. The safety related issues are critical, and Canadian research will be essential for making sure that these devices will enhance, rather than degrade, the overall safety of the driver/vehicle system.

In the future, mobile information systems will provide - in addition to positioning, navigation and route guidance - many capabilities, the use of which will quickly become second nature to us - to the extent that we will probably be wondering how we ever got along without them. These developments should happen in an orderly fashion: preferred practises, uniform design criteria and official standards ought to be developed prior to wide use of these systems. This requires action now.

APPENDICES

A. REFERENCES

B. REPRESENTATIVE SAMPLING OF SPECIFICATIONS & CONFIGURATIONS

C. HUMAN FACTORS CONSIDERATIONS
SELECTED EXCERPTS

D. CLASSIFICATION OF USERS, SUPPLIERS AND REGULATORS

E. INTERVIEW GUIDE

F. STANDARDS FOR MARINE CARTOGRAPHY
SELECTED NOTES ON ACTIVITIES

APPENDIX A

REFERENCES

A.1 REFERENCES - SECTION 1

A.2 REFERENCES - SECTION 2

APPENDIX A.1

REFERENCES

[Section 1]

1 A HISTORY OF MECHANICAL INVENTIONS
Usher A P, Harvard University Press, Revised Edition, 1954.

2 SCIENCE AND CIVILISATION IN CHINA
Needham J/University of Cambridge, Mechanical Engineering: Vol 4/Part II, Cambridge at the University Press, England, 1965.

3 SCIENCE AND CIVILISATION IN CHINA
Needham J/University of Cambridge, Physics: Vol 4/Part I, Cambridge at the University Press, England, 1962.

4 VEPOL - A VEHICULAR PLANIMETRIC DEAD-RECKONING COMPUTER
Meyer J H/Hughes Research Labs, IEEE Transactions on Vehicular Technology: Vol VT-20/p.62-68, Aug 1971.

5 SOME REMARKABLE MECHANICAL ROAD GUIDES
Perry H W, Scientific American: Vol 104/No 2/p.33&47-48, 14 January 1911.

6 CHADWICK
Ellis W D, True's Automobile Yearbook: No 2/p.88-89&132-133, 1953.

7 ROUTE INDICATOR
Rhodes J B, U.S. Patent No. 1 005 474, 10 October 1911.

8 ROUTE-INDICATOR FOR AUTOMOBILES
Lindenthaler F J & Pretz J, U.S. Patent No. 915 976, 23 March 1909.

9 NEW MAPPING INSTRUMENT BY CORPS OF ENGINEERS
Faustman D J/U.S.Army, Surveying and Mapping: Vol V/No 3/p.30-37, July 1945.

10 THE VEHICULAR ODOGRAPH
McNish A G & Tuckerman B/Carnegie Institute of Washington, Terrestial Magnetism and Atmospheric Electricity: Vol 52/No 1/p.39-65, 1947.

11 LAND-VEHICLE NAVIGATION SYSTEM
Spracklen S G/Aviation Electronics Ltd, Industrial Electronics: Vol 3/p.72-76, February 1965.

12 GEODESY FROM ASTROLABE TO GPS - A NAVIGATOR'S VIEW
Luse James D & Malla R/Interstate Electronics Corporation, Navigation: Vol 32/No 2/p.101-113, Summer 1986.

13 AUTOMATIC ROUTE CONTROL SYSTEM
French R L & Lang G M/Avcon Inc, IEEE Transactions on Vehicular Technology: Vol VT-22/p.36-41, May 1973.

14 A NOVEL APPROACH TO AUTOMOTIVE NAVIGATION AND MAP.DISPLAY
Honey S K & Zavoli W B/Etak Inc, Land Navigation and Location for Mobile Applications/RIN Conference: Proceedings/Paper #27, York, England, 9-11 September 1985.

14a AUTOMOBILE NAVIGATION: WHERE IS IT GOING?
French R L/Consultant, IEEE Aerospace and Electronic Systems Society Magazine: Vol 2/No 5, May 1987.

15 HISTORICAL OVERVIEW OF AUTOMOBILE NAVIGATION TECHNOLOGY
French R L/Consultant, 36th IEEE Vehicular Technology Conference: Proceedings/p.350-358, Dallas, Texas, 20-22 May 1986.

15a AUTONOMOUS ROUTE GUIDANCE USING ELECTRONIC DIFFERENTIAL ODOMETER DEAD-RECKONING WITH VECTORIZED MAP-MATCHING
French R L/R R A Routeware Division, U.S. Army Artificial Intelligence & Robotics Symposium: Proceedings-Part II/p.0/1-30, Indianapolis, Indiana, 12-13 September 1984.

16 LRV: FIRST ON THE FINAL FRONTIER
Katz J F/Automobile Quarterly, Automobile Quarterly: Vol 23/No 4/p.424-431, Fourth Quarter 1985.

17 AUTOMATIC VEHICLE MONITORING PROGRAM DIGEST
Urban Mass Transportation Administration, Report No. DOT-TSC-UMTA-81-11, April 1981.

18 STUDY OF THE FEASIBILITY AND DESIGN CONFIGURATION FOR IN-VEHICLE ROUTE GUIDANCE
Gordon R L & Soicher B & Donaldson E/Sperry Corporation, FHWA/U.S. DOT, Report No FHWA/RD-81/056, May 1981.

19 DAIR - A NEW CONCEPT IN HIGHWAY COMMUNICATIONS FOR ADDED SAFETY AND DRIVING CONVENIENCE
Hanysz E A & Quinn C E & Stevens J E & Trabold W G/General Motors Corporation, GM Report No GMR-600, 6 October 1966.

20 AN ELECTRONIC ROUTE GUIDANCE SYSTEM FOR HIGHWAY VEHICLES
Rosen D A & Mammano F J & Favout R/Bureau of Public Roads, IEEE Transactions on Vehicular Technology: Vol VT-19/p.143-152, February 1970.

21 NAVIGATION TECHNOLOGY STATUS AND DIRECTIONS IN JAPAN
Shibata M/Public Works Administration, TRB 65th Annual Meeting, January 1986.

22 THE CACS PROJECT AND NOW: DYNAMIC ROUTE GUIDANCE AS THE FINAL TARGET
Fujii H/Association of Electronic Technology for Automobile Traffic and Driving, TRB 65th Annual Meeting, 13-16 January 1986.

23 FUNCTION, EQUIPMENT, AND FIELD TESTING OF A ROUTE GUIDANCE AND INFORMATION SYSTEM FOR DRIVERS (ALI)
Braegas P/Blaupunkt-Werke GmbH, IEEE Transactions on Vehicular Technology: Vol VT-29/p.216-225, May 1980.

24 ALI-SCOUT - A UNIVERSAL GUIDANCE AND INFORMATION SYSTEM FOR ROAD TRAFFIC
Tomkewitsch R von/Siemens AG, IEE International Conference on Road Traffic Control: Proceedings/p.22-25, London, England, 15-18 April 1986.

25 AUTOGUIDE - A BETTER WAY TO GO?
U.K. Department of Transport, Discussion Document, 1986.

25a AUTOGUIDE - PILOT STAGE PROPOSALS
U.K. Department of Transport, Consultation Document, 1988.

26 CONSIDERATION OF THE VARIOUS ERROR SOURCES IN A PRACTICAL AUTOMATIC VEHICLE LOCATION SYSTEM
Jane R V/Motorola Inc, 34th IEEE Vehicular Technology Conference: Record/p.277-284, 21-23 May 1984.

27 II MORROW'S LORAN C BASED VEHICLE TRACKING SYSTEM
Bronson R & Sears W & Cortland L/II Morrow Inc, Land Navigation and Location for Mobile Applications/RIN Conference: Proceedings/Paper No 14, York, England, 9-11 September 1985.

28 USING CELLULAR TELEPHONES FOR AUTOMATIC VEHICLE TRACKING
Carter D A & Warburton R D H/Jaycor, Land Navigation and Location for Mobile Applications/RIN Conference: Proceedings/Paper No 28, York, England, 9-11 September 1985.

29 AUTOMOTIVE NAVIGATION SYSTEM
Dork R/General Motors Corporation, Detroit Engineer & Michigan Engineering: Vol 44/No 8/p.11-13, October 1983.

30 APPLICATIONS TO GOODS MOVEMENTS
Sabounghi R N/Transportation Development Centre/Transport Canada, TRB 65th Annual Meeting, January 1986.

31 CATHODE-RAY TUBE INFORMATION CENTER WITH AUTOMOTIVE NAVIGATION
Jarvis M W & Berry R C/Ford Motor Company, SAE Technical Paper Series: No 840313, 1984.

32 NOW: DRIVING BY SATELLITE
Lemonick M, Science Digest: Vol 92/p.34, December 1984.

33 NAVIGATION SYSTEMS USING GPS FOR VEHICLES
Itoh T & Okada Y & Endoh A & Suzuki K/Nissan Motor Co Ltd, SAE Technical Paper Series: #861360, 1986.

34 MITSUBISHI ELECTRIC AUTOMOTIVE PRODUCT SPECIFICATION SHEET: GPS/NAVSTAR
.

35 TERRESTRIAL EVALUATION OF THE GPS STANDARD POSITIONING SERVICE
Mooney F W/U.S. DOT, Navigation: Vol 32/No 4/p.351-369, Winter 1986.

36 SPACE-BASED NAVIGATION: PAST, PRESENT, AND FUTURE
Helms C W & Logsdon T S/Rockwell International, AIAA Meeting and International Aerospace Exhibit, Washington,D C, 1 May 1984.

37 GEOSTAR POSITIONING ANALYSIS
Richards R T & Snively L O/Geostar Corporation, IEEE Position Location and Navigation Symposium: Proceedings/p.13-19, 4-7 November 1986.

38 MOBILE SATELLITE SERVICES FOR TRANSPORTATION INDUSTRIES
Anderson R E/Mobile Satellite Corporation, TRB 65th Annual Meeting, January 1986.

39 RECENT OBSERVATIONS WITH THE SOVIET UNION'S GLONASS NAVIGATION SATELLITES
Dale S A & Daly P/University of Leeds, IEEE Position Location and Navigation Symposium: Proceedings/p.20-25, 4-7 November 1986.

40 ON-BOARD VEHICLE ROUTE INSTRUCTIONS VIA PLASMA DISPLAY PANEL
French R L/Avcon Inc, SID International Symposium: Digest of Technical Papers/Vol 5/p.146-147, 1974.

41 APPLICATION OF THE COMPACT DISC IN CAR INFORMATION AND NAVIGATION SYSTEMS
Thoone M L G & Breukers R M A M/Philips, SAE Technical Paper Series: No 840156, 1984.

42 THE CARIN CAR INFORMATION AND NAVIGATION SYSTEM AND THE EXTENSION TO CARMINAT
Fernhout Herman C/Philips, Proceedings of the IEE Sixth International Conference on Automotive Electronics: pp.139-143, London, England, 12-15 October 1987.

43 EVA - AN ELECTRONIC TRAFFIC PILOT FOR MOTORISTS
Pilsak O/Blaupunkt-Werke GmbH, SAE Technical Paper Series: No 860346, 1986.

44 NEW NAVIGATION SYSTEM, MAPIX-III
Ikeda M & Fukaya H & Tabe T/ , 16th International Symposium on Automotive Technology & Automation: Proceedings/Volume II/p.61-67, Florence, Italy, 11-15 May 1987.

45 SUMITOMO ELECTRIC'S AUTOMATED VEHICLE LOCATION AND NAVIGATION SYSTEMS
Doi H/Sumitomo Electric Industries Ltd, SAE International Congress and Exposition: Presentation, Detroit, Michigan, 23-27 February 1987.

46 NAVIGATION SYSTEMS FOR PASSENGER CARS
Tsunoda M & Itoh T & Ishikawa S & Iwabuchi M/Nissan Motor Co Ltd, SAE Technical Paper Series: #861056, 1986.

47 DEVELOPMENT OF VIBRATIONAL RATE SENSOR AND NAVIGATION SYSTEM
Oikawa T & Aoki Y & Suzuki Y/Yazaki Corp, SAE Technical Paper Series: No 870215, 1987.

48 PACKET RADIO CAN BE A COST-EFFECTIVE ALTERNATIVE TO DEDICATED LAND LINES FOR DATA COMMUNICATION NETWORKS
Beeferman S/Dataradio Corporation, Communications News: Vol 23/No 8/p.36-38, August 1986.

49 AUTOMATIC RADIO INFORMATION (ARI) - APPLICATION IN EUROPE AND THE U.S.
Flynn D/Blaupunkt Division, Robert Bosch Sales Corp, Conference on In-Vehicular Motorist Information Systems: Summary/p.25-26, McLean, Virginia, 18-20 September 1984.

50 OKE - AN AUTOMATIC POSITION FIXING-SYSTEM FOR OPERATIONAL VEHICLES
Henkel R & Urbanski W/Robert Bosch Research Institute, Internal Publication, 1986.

51 EXPERIMENTAL ROUTE GUIDANCE HEADS UP DISPLAY RESEARCH
Benzinger R W & Bell E/Kollsman Instrument Corporation, HRB/Research Record No 265/p.62-70, 1968.

52 INTERFACE CONSIDERATIONS IN THE DESIGN OF AN ELECTRONIC NAVIGATOR
Streeter A/Bell Laboratories, Paper presented at International Symposium on Computer Assisted Cartography (AutoCarto 7), Washington D C, 11-14 March 1985.

53 ROUTE INFORMATION SYSTEMS - SIGNPOSTS OF THE FUTURE
Wootton H J & Brett A C/Wootton Jeffreys Consultants plc, 2nd IEE International Conference on Road Traffic Control, Proceedings/p.15-17, London, England, 15-18 April 1986.

53a GUIDELINES AND SOME DEVELOPMENTS FOR A NEW MODULAR DRIVER INFORMATION SYSTEM
Zimdahl W/Volkswagen Werke GmbH, Proceedings of the 34th IEEE Vehicular Technology Conference: pp.178-182, Pittsburgh, Pennsylvania, 21-23 May 1984.

54 ON-BOARD COMPUTER SYSTEM FOR NAVIGATION, ORIENTATION AND ROUTE OPTIMIZATION
Haeussermann P/Daimler-Benz AG, SAE Technical Paper Series: No 840485, 1984.

54a THE DRIVER GUIDE SYSTEM
Mitamura K & Chujo S & Senoo T/Nissan Motor Company, SAE Technical Paper Series: No 830660, 1983.

55 ELECTRO GYRO-CATOR, NEW INERTIAL NAVIGATION SYSTEM FOR USE IN AUTOMOBILES
Tagami K & Takahashi T & Takahashi F/Honda R&D Company, SAE Technical Paper Series: No 830659, 1983.

56 VEHICLE LOCATION MONITORING SYSTEM
Henson A J & Lewis R W/The Boeing Company, U.S. Patent No. 3 789 198, 29 January 1974.

57 A DEAD RECKONING/MAP.CORRELATION SYSTEM FOR AUTOMATIC VEHICLE TRACKING
Lezniak T W & Lewis R W & McMillan R A/The Boeing Company, IEEE Transactions on Vehicular Technolo-gy: Vol VT-26/p.47-60, February 1977.

58 TIGER PRELIMINARY DESIGN AND STRUCTURE OVERVIEW
Broome F R/U.S. Census Bureau, Association of American Geographers: Annual Meeting, 1984.

59 THE NORTH AMERICAN STREET MAP: DEVELOPING A NAVIGATIONAL DATA BASE
Karlin B W/Karlin & Collins Inc, Paper presented at North American Cartography Information Society 7th Annual Meeting (NACIS VII), Atlanta, Georgia, 28-31 October 1987.

60 DIGITAL CARTOGRAPHIC DATA STANDARDS: AN INTERIM PROPOSED STANDARD
Moellering H/Editor, National Committee for Digital Cartographic Data Standards: Report #6, 1985.

61 ROAD/VEHICLE ELECTRONIC COMMUNICATION, ELECTRONIC TRAFFIC AIDS ON MAJOR ROADS
EUCO-COST 30 bis/Organization for Economic Cooperation and Development, Working Group.1: Final Report/205/84, 1984.

62 FUTURE OF TRAFFIC CONTROL DEVICES: COMMUNICATION WITH MOTORISTS
Stephens B W/FHWA, (to be published), 1987.

63 SMART COMPASS PILOTS A CAR TO IT'S DESTINATION
Gosch J/ , Electronics: Vol 59/No 21/p.20-21, 1986.

64 AUTOMOTIVE NAVIGATION SYSTEM
Totani S & Kato T & Muramoto K/Nippondenso, SAE Technical Paper Series: No 830910, 1983.

65 THE UTILITY OF LOW COST VEHICLE NAVIGATION SYSTEMS FOR FLEET MANAGEMENT APPLICATIONS
Honey S K & White Jr M S & Zavoli W B/Etak Inc, SAE Technical Paper Series: #870217, 1987.

66 VEHICLE NAVIGATION SYSTEM TAKES CARE OF BUSINESS
/ , High Technology: p.7, August 1985.

67 THE TELECOM VAN THAT MAZDA BUILT
Troise J/ , Network World: p.31-33, 2 June 1986.

68 THE PROMETHEUS PROJECT
William M & Preston N C G N/Gaydon Technology Ltd, Sixth International Conference on Automotive Electronics: Proceedings/Part 2/p.36-38, London, England, 12-15 October 1987.

69 A DELPHI PANEL-DERIVED SCENARIO ON ROAD TRANSPORT INFORMATICS EVOLUTION
Sviden O/International Institute for Applied Systems Analysis, April 1987.

70 THE ATLAS AND CARMINAT PROJECTS: COMMUNICATICNS BETWEEN DRIVER, AUTOMOBILE AND ENVIRONMENT
Monty A B/Renault Research Division, Sixth International Conference on Automotive Electronics: Proceedings/p.129-138, London, England, 12-15 October 1987.

71 APPLICATIONS OF INFORMATION AND TELECOMMUNICATIONS TECHNOLOGIES TO ROAD SAFETY
Queree C/MVA Systematica, Sixth International Conference on Automotive Electronics: Proceedings/p.156-158, London, England, 12-15 October 1987.

72 AUTO NAVIGATION AND TRAFFIC DATA IN REAL TIME
--/--, Science and Technology in Japan: p.66-67, August 1987.

73 RESEARCH INTO ELECTRONIC MAPS AND AUTOMATIC VEHICLE LOCATION SYSTEMS
Krakinsky E J & Karimi H A & Harris C & George J/University of Calgary, Eight International Symposium on Computer-Assisted Cartography: Proceedings/p.572-583, 29 March - 3 April 1987.

74 ECONOMIC ASSESSMENT OF POTENTIAL SOLUTIONS FOR IMPROVING MOTORIST ROUTE FOLLOWING
King G E/KLD Associates Inc, FHWA Report/RD-86/029/Vol 1, 1986.

75 POTENTIAL BENEFITS OF ROUTE GUIDANCE
King G E/KLD Associates Inc, TRB 65th Annual Meeting, 13-16 January 1986.

76 ADVANCED TECHNOLOGY FOR ROAD FREIGHT TRAFFIC MONITORING AND CONTROL
Schmitt L A/Arizona DOT & Davies P/Castle Rock Consultants & West P/University of Nottingham, Second International Conference on Road Traffic Control: Proceedings/p.43-46, London, England 15-18 April 1986.

77 WIDE AREA VEHICLE MONITORING (WAVM) SYSTEM PLROJECT FOR ONTARIO's TRUCKING INDUSTRY
Tsai J/Ministry of Transportation of Ontario, Roads and Transportation Association of Canada meeting, Toronto, Canada, 29 September- 2 October 1986.

78 FEASIBILITY OF A NATIONAL HEAVY VEHICLE MONITORING SYSTEM
Grenzefeck L R et al/A D Little Inc, NCHRP.Project 3-34: Interim Report, January 1987.

79 PROCEEDINGS OF THE CALTRANS CONFERENCE ON TECHNOLOGY OPTIONS FOR HIGHWAY TRANSPORTATION OPERATIONS
--/California Department of Transportation, Sacramento, California, 28-31 October 1986.

80 TOYOTA ELECTRO MULTIVISION
Shoji Y & Horibe T & Kondo N/Toyota Motor Corporation, SAE Technical Paper Series: No 880220, 1988.

81 MOBILE PHONES' BUSINESS APPEAL
Barney K/ , Nation's Business: Vol 74/No 8/p.38, August 1986.

82 USE OF NOAA WEATHER RADIO FOR MOTORIST INFORMATION
Conte J/Jacor, Conference on In-Vehicular Motorist Information Systems: Summary/p.26-28, McLean, Virginia, 18-20 September 1984.

83 ARI-AUTOMATIC RADIO INFORMATION
Duckeck H G/Blaupunkt-Werke GmbH, SAE Technical Paper Series: No 840091, 1984.

84 CELLULAR TELEPHONE - NEW TECHNOLOGY AND APPLICATIONS FOR MOTORIST INFORMATION
Loderstedt R/Bell Atlantic Mobile Systems, Conference on In-Vehicular Motorist Information Systems: Summary/p.17-18, McLean, Virginia, 18-20 September 1984.

85 ROUTE GUIDANCE AND DRIVER INFORMATION SYSTEMS - AN OVERVIEW
Russam K & Jeffery D J/Transport and Road Research Laboratory, 2nd IEE International Conference on Road Traffic Control: Proceedings/p.1-5, London, England, 15-18 April 1986.

86 THE GBF/DIME SYSTEM: DEVELOPMENT, DESIGN AND USE
Silver J/U.S. Census Bureau, Joint Annual Meeting of the American Society of Photogrammetry and the American Congress on Surveying and Mapping, 1977.

87 OVERVIEW: HUMAN FACTORS DESIGN CONSIDERATIONS
Stephens B W/FHWA, TRB 65th Annual Meeting, January 1986.

88 COMMUNICATION BETWEEN INFORMATION BEACONS AND VEHICLES PROVIDED WITH INFRARED EQUIPMENT
Tomkewitsch R von/Siemens AG, Micro-Electronics for Road and Traffic Management Seminar, Tokyo, 1984.

89 KEEPING TABS ON CARS AND TRUCKS
Zygmont J/High Technology, High Technology: Vol 6/No 9/p.18-23, September 1986.

90 DIGITAL ELECTRONIC MAPPING OF EUROPEAN TERRITORY (DEMETER)
Heres L/Philips + Claussen H & Leichtner W/University of Hanover + Schlogel D/ Robert Bosch,
18th International Symposium on Automotive Technology and Automation: Proceedings/Vol 2/Paper No 88082,
Florence, Italy, 30 May - 3 June 1988.

Note: underlined reference numbers not cited in text.

APPENDIX A.2

REFERENCES

[Section 2]

101 THE EFFECT OF GRAPHIC INPUT DEVICES ON PERFORMANCE IN A CURSOR POSITIONING TASK
Albert A E/ , Human Factors Society 26th Annual Meeting: Proceedings, Seattle, Washington, 1982.

102 AMERICAN NATIONAL STANDARD FOR HUMAN FACTORS ENGINEERING OF VISUAL DISPLAY TERMINAL WORKSTATIONS
/ , Revised Review Draft, July 1986.

103 THE PSYCHOLOGY OF HUMAN-COMPUTER INTERACTION
Card S K & Moran T P.& Newell A/Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1983.

104 EVALUATION OF CRT-DISPLAYED DIGITAL IMAGERY USING SUBJECTIVE SCALING
Chao B et al/ , Human Factors Society 26th Annual Meeting: Proceedings, Seattle, Washington, 1982.

105 HUMAN FACTORS GUIDELINES FOR THE USE OF SYNTHETIC SPEECH DEVICES
Edman T R/ , Human Factors Society 26th Annual Meeting: Proceedings, Seattle, Washington, 1982.

106 DESIGN HANDBOOK FOR IMAGERY INTERPRETATION EQUIPMENT
Farrell R T & Booth J M/Boeing Company, Boeing Technical Report D180-19063-1, December 1975.

107 SEHEN UND VERKEHR (Springer)
Gramberg-Danielsen B/ , , 1967.

108 DRIVER UNDERSTANDING OF FUEL AND ENGINE GAUGES
Green P/ , Electronic Displays and Information Systems SP-565, International Congress and Exposition, Society of Automotive Engineers Inc (SAE), Warrendale, Pennsylvania, 1984.

109 SYNTHESIZED WARNING MESSAGES
Hakkinen M T & Williges B H/ , Human Factors Journal, 1984.

110 HUMANSCALE
/Henry Dreyfuss Associates, The MIT Press, Cambridge, Massachusetts, 1981.

111 THE PERCEPTION OF FLICKER AND GLARE ON COMPUTER CRT DISPLAYS
Isensee S/ , Human Factors Society 26th Annual Meeting: Proceedings, Seattle, Washington, 1982.

112 HUMAN FACTORS - UNDERSTANDING PEOPLE SYSTEM RELATIONSHIPS
Kantowitz & Sorkin/John Wiley and Sons, New York, 1983.

113 COLOR DISPLAY DESIGN GUIDE
Krebs M J & Wolfe J D & Sandvig J H/ , Office of Naval Research Report ONR-CR213-136-2F, 1978.

114 HUMAN FACTORS IN ENGINEERING AND DESIGN
McCormick E J & Sanders M S/ , McGraw-Hill Inc , 5th Edition, New York, 1982.

115 HUMAN FACTORS DIMENSIONS IN THE EVALUATION OF INCREASINGLY AUTOMATED CONTROL ROOMS FOR NEAR-EARTH SATELLITES
Mitchell C M et al/ , Human Factors Society 26th Annual Meeting: Proceedings, Seattle, Washington, 1982.

116 AGE AND INFORMATION PROCESSING
Morsel J/ , Human Factors Society 26th Annual Meeting: Proceedings, Seattle, Washington, 1982.

117 LUMINANCE SPECIFICATIONS FOR AUTOMOBILE INSTRUMENT PANELS
Mourant R R & Langolf G D/ , Human Factors: Vol 18/No 1, 1976.

118 ESTIMATING THE AMOUNT OF EYE MOVEMENT DATA REQUIRED FOR PANEL DESIGN AND INSTRUMENT PLACEMENT
Seeberger J J & Wierwille W W/ , Human Factors: Vol 18/No 3, 1976.

119 THE ATTENTIONAL DEMAND OF AUTOMOBILE DRIVING
Senders J W & Kristofferson A B & Levison W H & Dietrich C W & Ward J L/ , Highway Research Record No 195, 1967.

120 ERGONOMICS STANDARDS AND RESEARCH FOR CARS
Simmonds G R W/ , Applied Ergonomics: 14.2, June 1983.

121 ELECTRONIC DISPLAYS - THE DEVELOPMENT OF AN ERGONOMICS HANDBOOK
Simmonds G R W & Galer M D/ , Electronic Displays and Information Systems SP-565, International Congress and Exposition/SAE, Warrendale, Pennsylvania, 1984.

122 AN ASSESSMENT OF FOUR COCKPIT DISPLAYS
Wozniak et al/ , Human Factors Society 28th Annual Meeting: Proceedings, 1984.

123 PERIPHERAL DETECTION OF REFLECTORIZED LICENSE PLATES
Zwahlen H T/Ohio University, Human Factors Society 30th Annual Meeting: Proceedings, Dayton, Ohio, 1986.

124 OPTIMAL PLACEMENT OF REFLECTIVE PAVEMENT MARKERS
Zwahlen H T/Ohio University, Prepared for Ohio DOT in Cooperation with FHWA/US DOT, State Job No 14354(0), Final Report No FHWA//OH-86/003, August 1985.

125 DRIVER EYE SCANNING, THE INFORMATION ACQUISITION PROCESS AND SOPHISTICATED IN-VEHICLE INFORMATION DISPLAYS AND CONTROLS
Zwahlen H T/Ohio University, Ninth Congress of the International Ergonomics Association: Proceedings, Bournemouth, England, 2-6 September 1985.

126 DRIVER EYE SCANNING ON CURVES AND ON STRAIGHT SECTIONS ON RURAL HIGHWAYS
Zwahlen H T/Ohio University, Human Factors Society 26th Annual Meeting: Proceedings, Seattle, Washington, 1982.

127 VERKEHRSSICHERHEIT
Zwahlen H T/Ohio University, 26, 4, 1980.

128 DRIVER EYE SCANNING BEHAVIOR IN RAIN AND DURING AN UNEXPECTED WINDSHIELD WIPER FAILURE
Zwahlen H T/Ohio University, Zeitschrift fur Verkehrssicherheit/p.148-155, 1980.

129 DRIVER EYE SCANNING BEHAVIOR AT TUNNEL APPROACHES
Zwahlen H T/Ohio University, Effects of Environmental Transitions on Highway Tunnel Operations and Safety, Task No 6, FHWA Contract No DOT-FH-11-8599, Prepared for Franklin Institute Research Laboratories, Project No C4114, Final Report, February 1979.

130 THE EFFECT OF ALCOHOL ON DRIVING SKILLS AND REACTION TIMES
Zwahlen H T/ , Journal of Occupational Accidents: Vol 1/No 1, July 1976.

131 A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF AUTOMOBILE PATH DEVIATION WHEN DRIVER STEERS WITH NO VISUAL INPUT
Zwahlen H T & Balasubramanian K N/ , Transportation Research Record No 520, 1974.

132 SAFETY ASPECTS OF CRT TOUCH PANEL CONTROLS IN AUTOMOBILES
Zwahlen H T & DeBald D P/ , 16th International Symposium on Automotive Technology and Automation: Proceedings, Florence, Italy, 1987.

133 SAFETY ASPECTS OF SOPHISTICATED IN-VEHICLE INFORMATION DISPLAYS AND CONTROLS
Zwahlen H T & DeBald D P/ , Human Factors Society 30th Annual Meeting: Proceedings Vol 1, Dayton, Ohio, 1986.

APPENDIX B

REPRESENTATIVE SAMPLING OF SPECIFICATIONS AND CONFIGURATIONS

FOR SYSTEMS LISTED IN EXHIBIT 13 / P.69-71

APPENDIX B.1 - ETAK NAVIGATOR

APPENDIX B.2 - NISSAN DELIVERY VAN

APPENDIX B.3 - FORD TRIPMONITOR

APPENDIX B.4 - MAPIX III SYSTEM

APPENDIX B.5 - PHILIPS CARIN

APPENDIX B.6 - TOYOTA SYSTEM

APPENDIX B.7 - YAZAKI SYSTEM

APPENDIX B.8 - MITSUBISHI SYSTEM

The ETAK NAVIGATOR. Mapping the future of driving.

Point A: Where we are today.

When the first automobile was built nearly a hundred years ago, it had a very simple purpose: to get people from where they were, Point A, to where they needed to be, Point B—more quickly, more comfortably, and more economically.

But somewhere along the road between Point A and Point B, something happened. Millions of automobiles quickly filled thousands of miles of roadway. Traffic congestion became the rule rather than the exception. And driving often became a frustrating confusion of paper maps, incomprehensible directions, wasted time and gas, missed or late appointments.

Point B: Where we're going.

An incredible new product called the ETAK NAVIGATOR™ is about to map a whole new course for the driving world, once again making it simple to get from Point A to Point B.

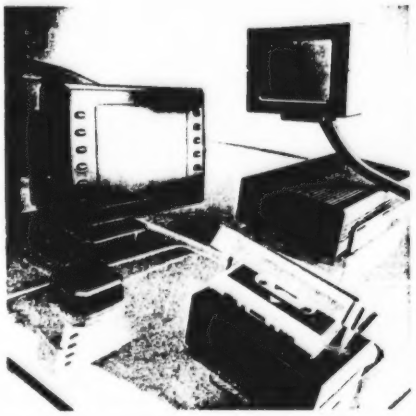
The NAVIGATOR™ takes the form of a small, smartly designed monitor mounted within easy view of the driver. Electronic maps, called ETAKMAPs,™ are displayed on the screen, continuously showing your vehicle's exact position.

Enter a destination.

A few simple button pushes and the address of your destination is entered into the NAVIGATOR. Automatically, a blinking star indicates its exact location. With the NAVIGATOR, finding an efficient route to wherever it is you are going is simple—just make your way to the destination star.

View the world around you.

Push a button and you zoom in for a close-up of your current location, with every street clearly shown. Or zoom out for a metropolitan overview, with your location and your destination still displayed. Simply select the zoom level you want, and you'll see a specially tailored map that clearly shows the information you need to find your destination easily and efficiently.



SPECIFICATIONS

POWER CONSUMPTION
- 12v, 36 watts—operating
- 12v, 12 watts—standby

DISPLAY
- Model 700, 7 inch screen (diagonal)
- Model 450, 4½ inch screen (diagonal)
- Vector graphic display
- 1024H x 770V resolution
- Automatic brightness control
- Antiglare screen

TAPE DRIVE
- 5" x 2¾" x 3¾", 80 ips

ELECTRONICS PACKAGE
- 12½" x 7" x 4"

COMPASS
- Solid state flux-gate magnetic sensor

NAVIGATION TECHNIQUE
- Dead reckoning, augmented with map correlation

AVERAGE POSITIONAL ACCURACY
- Within 50 feet

MAP SCALE
- Variable from ¼ mile to 10 miles

Never get lost.

The NAVIGATOR display always shows you exactly where you are. Just start your car and drive away. Now glance at your NAVIGATOR screen to see your current location and the location of your destination. Never before has it been this easy to get from Point A to Point B. And with the NAVIGATOR, **you'll never get lost again.**

New capabilities for the NAVIGATOR.

ETAKMAPs provide the key to the NAVIGATOR's versatility. Prepared by geographic region, ETAKMAPs store information that makes the NAVIGATOR function. Periodic revisions will incorporate newly built roads as well as new features and functions for the NAVIGATOR. In the future, specialized ETAKMAPs will show the locations of roadside services, tourist attractions, and local businesses. So, the NAVIGATOR you buy today will provide you with a wide range of capabilities tomorrow—for the modest price of a new ETAKMAP.

Simplicity: The ultimate sophistication.

Everything about the NAVIGATOR says sophistication, from its modern design to its leading-edge componentry. Yet its greatest sophistication is really its simplicity. It's easy to learn and easy to use, with a surprisingly low price that makes it easy to afford. Then, of course, there's the primary reason the NAVIGATOR was created in the first place: **to make it easy once again to get from Point A to Point B.**

Find out for yourself just how easy that is. The ETAK NAVIGATOR.

Ask your dealer for a test drive today.

ETAK

1455 Adams Drive
Menlo Park, CA 94025

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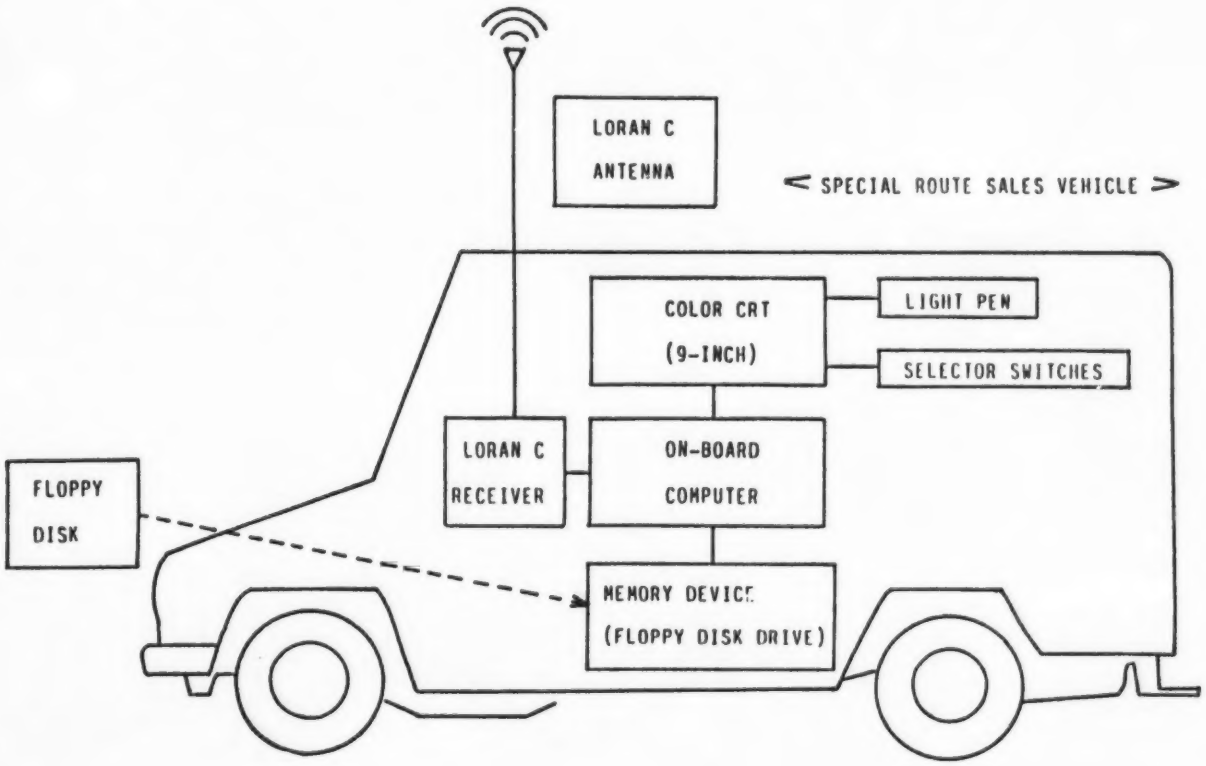
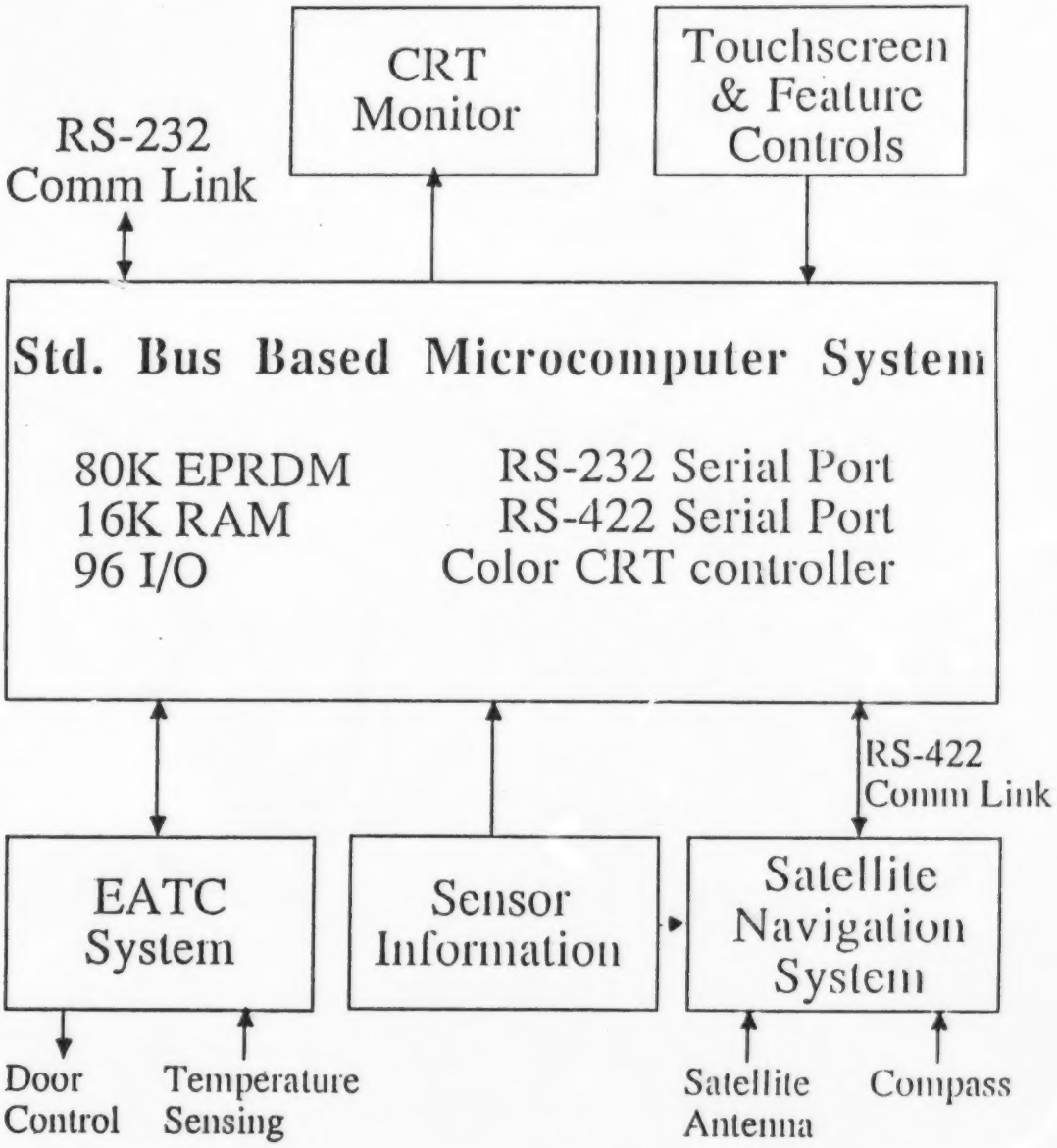
APPENDIX B.2 - NISSAN DELIVERY VAN

DELIVERY NAVIGATION SYSTEM - SYSTEM DIAGRAM



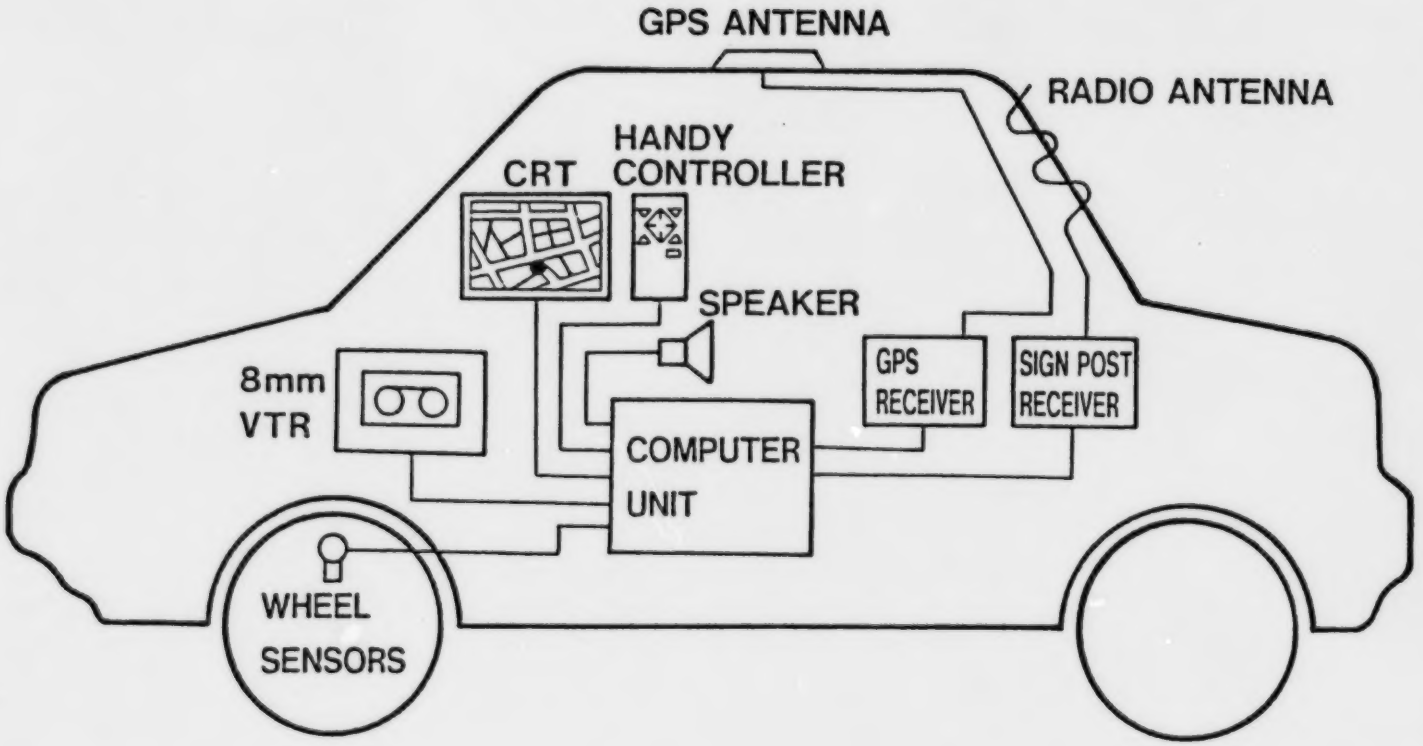
FUNCTIONS
* Delivery destination list display
* Delivery sequence display
* Delivery destination detailed information display (Map of locality)
* Change of delivery sequence
* Vehicle position display

NISSAN MOTOR CO., LTD.



Ford Tripmonitor System Diagram

Source: Ref 31



MAPIX-III System Configuration

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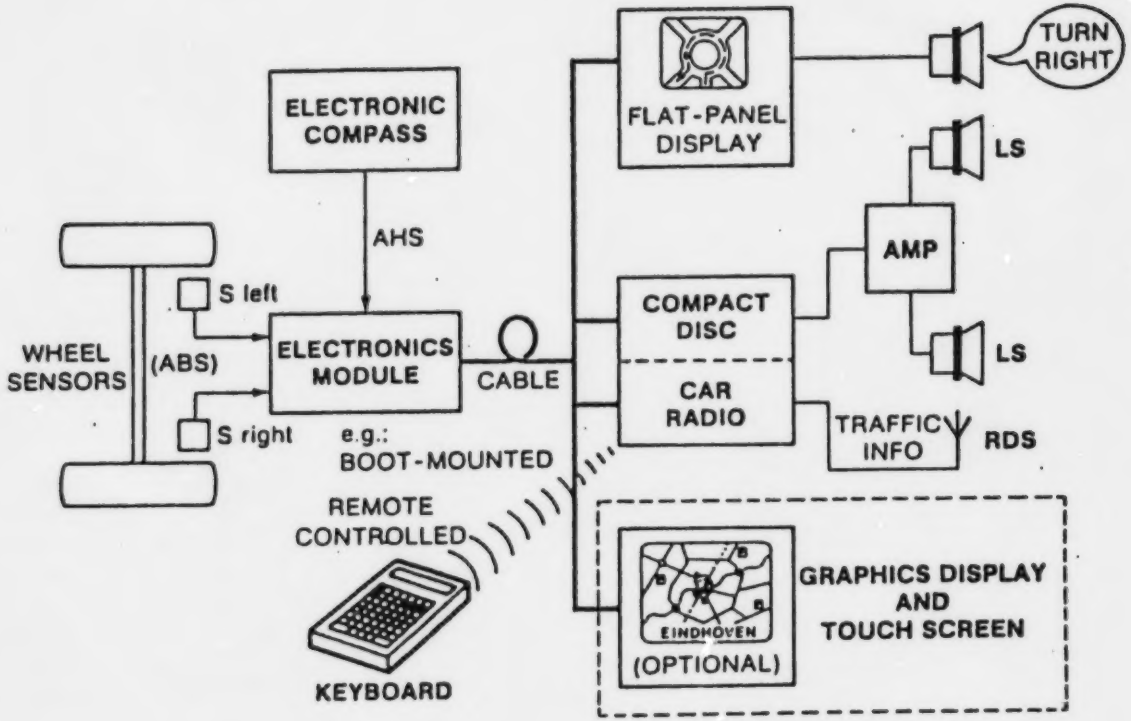
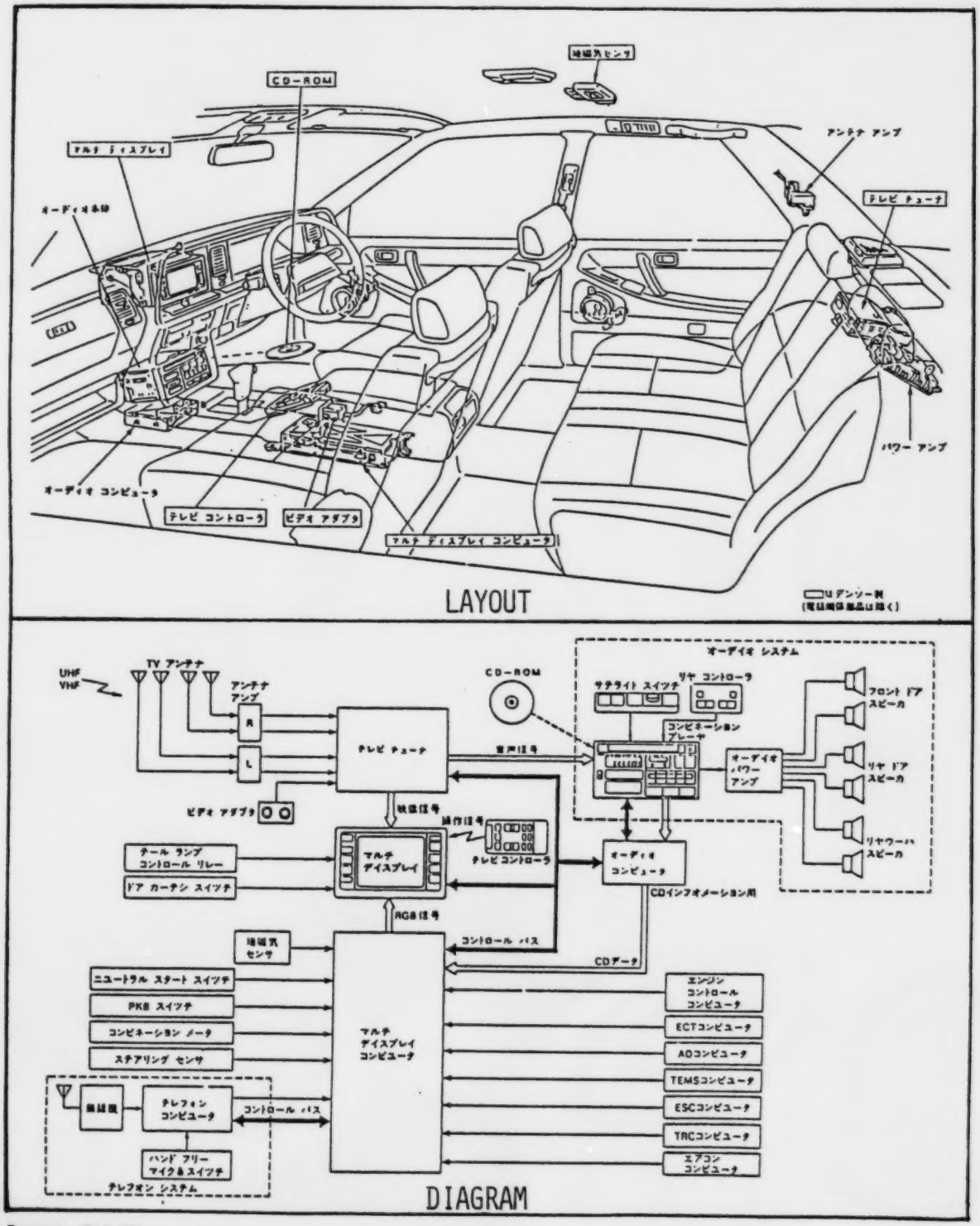


Block diagram of a CARIN-II prototype system.

Source: Ref 42

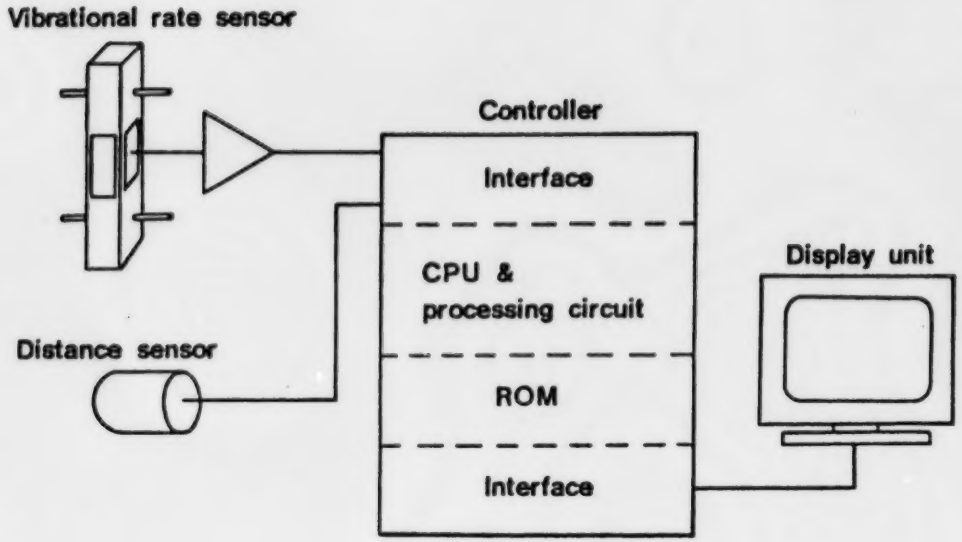
APPENDIX B.6 - TOYOTA SYSTEM

TOYOTA ELECTRO MULTIVISION SYSTEM



Source: Ref 80

YAZAKI NAVIGATION SYSTEM



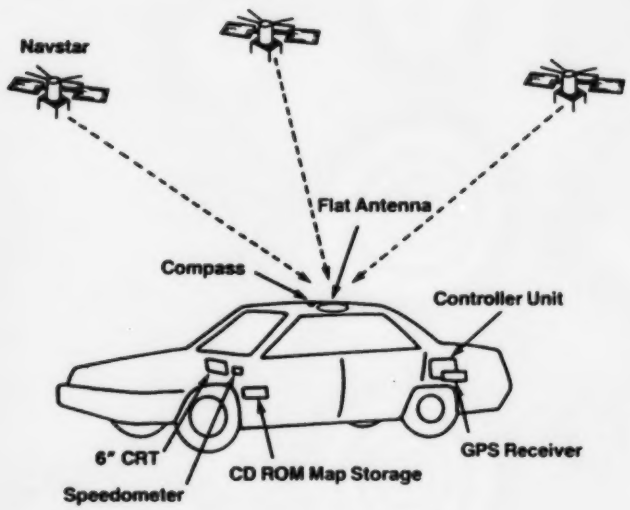
Source: Ref 47

GPS/NAVSTAR

Mitsubishi, jointly with Japan Radio Company, has developed the first practical automobile navigation system using satellites. This system automatically provides the operator a precise fix on a mapped location.

The highly accurate system is a combination of the Global Positioning System (GPS) and a vehicle navigation system, which consists of a GPS receiver, compass, speed sensor, flat patch antenna, control unit, map generator from CD ROM and color cathode ray tube (CRT) display that shows the car's position on a map.

Positional information from the satellites is combined with information from compass and speed sensors in the stand-alone navigation system. Analysis allows pinpointing the position of a car even in a tunnel or between high-rise buildings where radio reception from satellites may be poor or even impossible.



Specifications

GPS Receiver	Frequency: 1575.42 MHZ ± 1MHZ C/A code Accuracy: Within 100m (typically 30m)
Compass	Flux Gate
Speed Sensor	Pulse from vehicle speedometer
Control Unit	Cpu: 8086 (8 MHZ) Positioning: GPS + Compass and Speed Sensor Display: Location centered with automatic scroll. Zoom up and down.
CRT Monitor	Size: 6 inch Angle of Deflection: 90° RGB: 8 colors
Positional calculation	Matrix inversion of four variables; one time and three spatial coordinates. Comparison with stored CD ROM map data.
Flat Antenna	Incorporated into roof panel.

Applications

Police, Fire, and Emergency Vehicles
Personal Automobiles
Taxi Fleets
Charter and Inter-state Bus Lines
Trucking Firms

MITSUBISHI ELECTRIC SALES AMERICA, INC.
12623 Newburgh Road, Livonia, MI 48150
Telephone (313) 591-9144 / Facsimile (313) 397-3097

APPENDIX C

HUMAN FACTORS CONSIDERATIONS

SELECTED MATERIALS (CHAPTER 3)

APPENDIX C.1 - REACTION TIME AS A FUNCTION OF THE AMOUNT OF INFORMATION TO BE DECIDED UPON

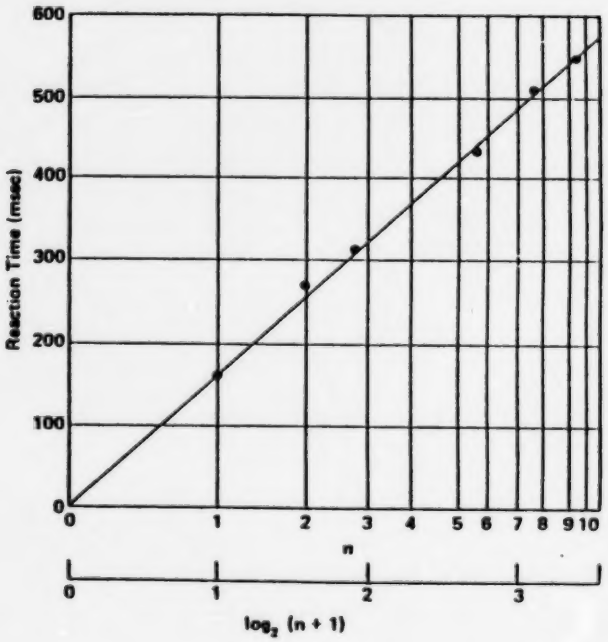
APPENDIX C.2 - NOTES ON EYE SCANNING TIMES AND PATH DEVIATIONS

APPENDIX C.3 - EYE SCANNING TIMES AS RELATED TO DRIVING ATTENTIONAL DEMAND AND DETERMINED BY VARIOUS AUTHORS

APPENDIX C.4 - ELECTRONIC DISPLAY DESIGN GUIDE (BY SIMMONDS/1983)

APPENDIX C.1

REACTION TIME AS A FUNCTION OF THE AMOUNT OF INFORMATION TO BE DECIDED UPON



Source: Ref 103 (Card et al, 1983)

Example: For 3 bits of information, the total choice/reaction time is approximately 0.49 seconds.

APPENDIX C.2

NOTES ON EYE SCANNING TIMES AND PATH DEVIATIONS

Reference # 128:

The centre of gravity of the x-y eye fixation pattern for a straight road was found to be 1.2 degrees to the right and 0.3 degrees above the focus of expansion and 4.6 degrees to the right, -0.6 degrees below the imaginary focus of expansion for a right curve. The study also compares the average

* fixation duration times
  - 0.44 seconds - straight
  - 0.27 seconds - right curve, and
* eye travel distances
  - 1.3 degrees - straight
  - 2.3 degrees - right curve,

and concludes that curve driving is a more demanding task than straight driving.

References # 131 & # 133:

Zwahlen/Balasubramanian were able to develop a mathematical model which relates the lateral standard deviation of an automobile in its lane to the speed of the vehicle and the occlusion distance of the driver (Ref 131). This model was validated in an experiment by Zwahlen/DeBald in which six drivers were asked to drive down a straight path while doing one of three things: looking ahead of the vehicle, reading text inside the vehicle, or driving with their eyes closed (Ref 133)

They determined that a driver of a 6 foot (1.83 m) wide vehicle in a 12 foot (3.66 m) wide lane, travelling at 30 MPH (48.3 km/h), reading text inside the vehicle for 2, 4 and 6 seconds would have probabilities of laterally deviating out of the lane of 0.05%, 1.1% and 8.7%, respectively. If the lane width were reduced to 10 feet (3 m) then these probabilities would increase to: 1.3%, 6.3% and 18.1%, respectively.

APPENDIX C.3

EYE SCANNING TIMES AS RELATED TO DRIVING ATTENTIONAL DEMAND AND DETERMINED BY VARIOUS AUTHORS

AUTHORS	EXPERIMENTAL CONDITIONS	TIME (s) or SPEED (mph)	
Gramberg - Danielsen (1967)	Time to accommodate on speedometer from 20m outside vehicle	age<40 age>60	0.4 to 0.8 2.0 to 2.7
Zwahlen Tunnel Study (1979)	Mean out of view time	Wheeling Pittsburgh Montreal	0.604 0.711 0.688
	Mean speed	Wheeling Pittsburgh Montreal	44.4 44.1 44.3
Zwahlen RRPM Study (1985)	Mean out of view time (curves 25 mph & tangents 55 mph)	Curves Tangents	0.34 0.53
Senders, et al. (1967)	Voluntary occlusion time (curves 25 mph & tangents 55 mph) for a viewing time of 0.5 seconds	Curves Tangents	0.32 1.97

EYE SCANNING TIMES AS RELATED TO DRIVING ATTENTIONAL DEMAND AND DETERMINED BY VARIOUS AUTHORS

notes

Based on the Gramberg-Danielsen (Ref 107) findings, provisions should be made so that an elderly driver (or a driver with degraded visual capacity) is not required to frequently obtain information internal to the vehicle.

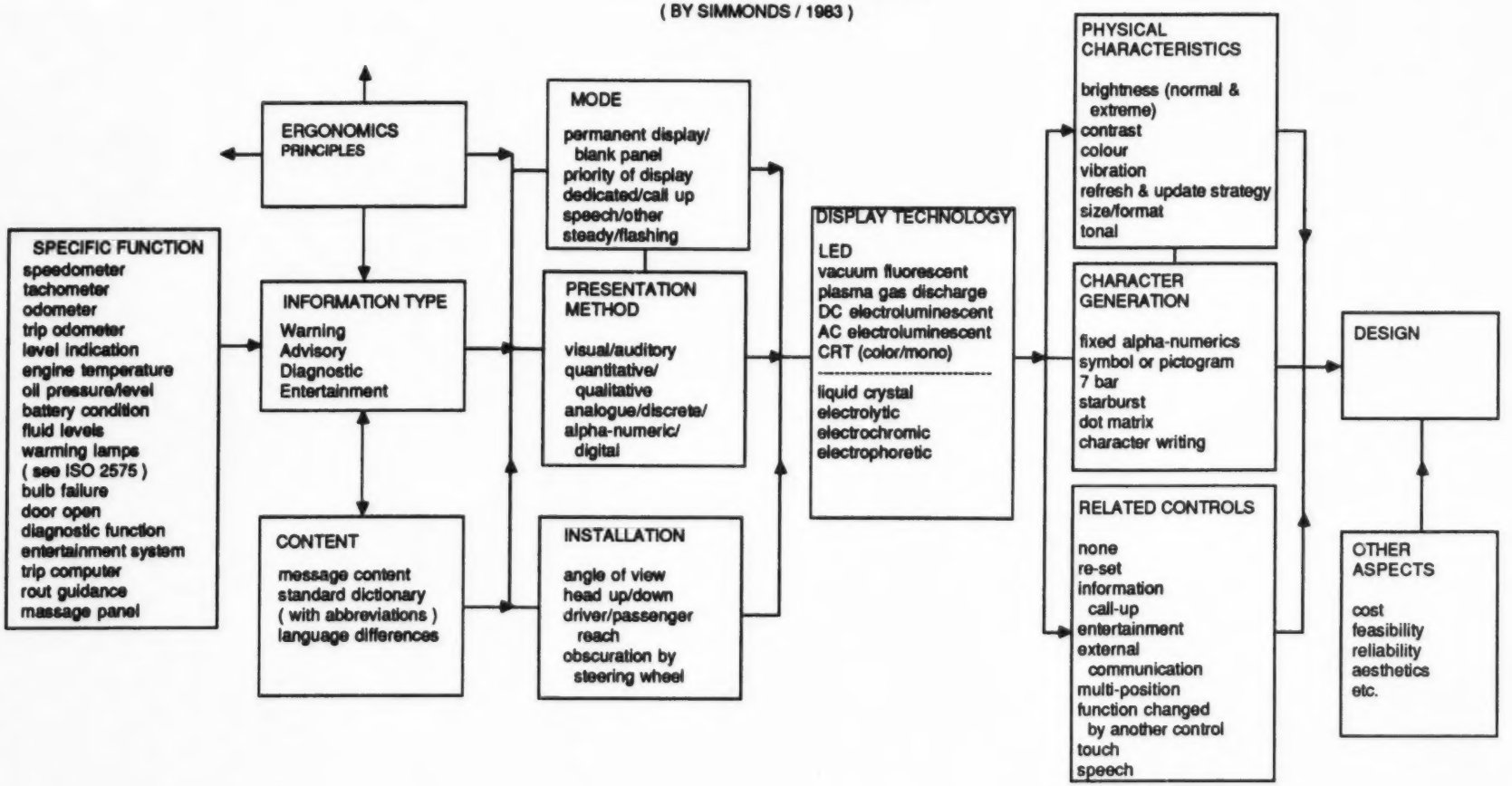
The mean out-of-view time for a person driving on a tangent section would be in the range of 0.5 to 2.0 seconds based on the work of Zwahlen (Ref 125 & 129) and Senders et al (Ref 119). Note, that the out-of-view time is the time when the driver is fixating inside the vehicle or blinking, in both the studies by Zwahlen, and is the occlusion time in the Senders study. The mean out-of-view times and mean speeds compare very closely for the three tunnels (Wheeling, Pittsburgh and Montreal) in the study by Zwahlen (1979). The out-of-view times are slightly higher in the Zwahlen (1979) Tunnel Study than in the Zwahlen (1985) RRPM Study (tangent road sections) but this is probably due to the increased speed of the later study.

Senders et al (Ref 119) and Zwahlen (Ref 125: RRPM Study) compare very closely for the out-of-view or occlusion time on curved sections of roadway at 25 MPH (Senders et al 0.32s vs. Zwahlen 0.34s). This would seem to indicate that curve driving is in fact more demanding than tangent driving and that the driver has less spare visual capacity when negotiating a curve. On the other hand, the two studies by Zwahlen differ by a large amount from the Senders et al study for the out-of-view time or occlusion time when driving tangent sections. This is probably due to the experimental design of Senders et al (1967) where the subjects were asked to control their occlusion time in a voluntary and conscious manner - therefore

APPENDIX C.4

ELECTRONIC DISPLAY DESIGN GUILDE

(BY SIMMONDS / 1983)



APPENDIX D

CLASSIFICATION OF USERS, SUPPLIERS AND REGULATORS

CLASSIFICATION OF USERS, PROVIDERS AND REGULATORS

Cat #	Grp #	Description
00		Control Groups: Project Steering Committees VNIS, etc
01		Road vehicle)
02		Off-road vehicle)
03		Rail vehicle) manufacturers
04		Rail (other)) of vehicles &
05		Marine) primary components
06		Sub-marine)
07		Aircraft)
08		Space vehicle)
10		Conventional route advisory (HAR, ARI, print-outs)
11		Dead Reckoning (without or with map matching)
12		Proximity Beacons
13		Radio (ground) - Loran C etc
14		Radio (satellite) - GPS etc
15		New systems
16		Hardware/software bundlers
20		Communications - equipment
21		Communications - services
22		Electronics (other) - equipment
23		Electronics (other) - services
24		Portable trip-recorders, scanners, etc
25		Base Data suppliers (surveyers, ...)
26		Map Data consolidators
27		Software Houses
28		FMIS Packages (fleet mgt info systems)
30		Federal Agencies
31		Provincial Agencies
32		Municipal Agencies
35		Military
37		Universities & other research facilities
40		Freight Carriers - road
41		Freight Carriers - rail
42		Freight Carriers - marine
43		Freight Carriers - air
44		Freight Consolidators
45		Tariff Bureaus (etc)
46		Freight Associations (all modes)
48		Freight+Pass Organizations (all modes)
50		Passenger Carriers - road
51		Passenger Carriers - rail
52		Passenger Carriers - marine
53		Passenger Carriers - air
54		Travel Agencies
55		Tourist Bureaus (etc)
56		Passenger Associations (all modes)

60 Consultants: mgt / transptn / electronics / communictns / ...
65 Individuals
70 Newsmedia: print / radio / TV

Associations

80 Federal)
81 Provincial) Mgt & Personnel
82 Municipal)

83 Utilities
84 Schools Boards & Teachers
85 Libraries & Community Information Centres

86 Parks & Recreation
87 Travel Industry

88 Social Services
89 Police, Fire and Ambulance

90 Roads & Traffic & Safety

91 Automobile Clubs, etc
92 Vehicle Manufacturing, Sales, Leasing and Maintenance

93 Resources: Agriculture, Forestry, Mining, ...
94 Conservation & Environment & Historical/Architectural & etc

95 - reserved (to split 96?)
96 Business Community
97 News Media
98 Others

99 Unclassified

APPENDIX E

INTERVIEW GUIDE

INTERVIEW GUIDE

Introduction

* We are undertaking a state-of-the-art review of Mobile Information Systems, of those rather modern in-vehicle devices that can provide:
  - location, self-contained navigation and interactive route guidance (some with map display)
  - vehicle monitoring, control and collision avoidance; and event recording (automatic, or keyed-in by the driver)
  - data&text management: retrieval, display and manipulation (personnal, LTL cargo, immediate surroundings, destintn)
  - mobile communications: receiving and transmitting of data (and possibly voice).
* The study is joint-funded by MTO and TDC/TC.
* Could we perhaps talk a few minutes about these systems; primarily, we would be interested to get an idea how they might be suited to the needs of your members/industry.

System Description

* Are you at all familiar with these systems (diagram on-hand)
  - is it something that your association or your members may have looked into recently ?
* Perhaps I could give you a description of the **range of capabilities** these systems are expected to have in the future (refer to 1-2 groups/p2, depending on respondent category):

Required Features

* How widely are these units in use already in your industry (throughout or specific types of carriers/operations/vehicle types) - ie. as share of total number of power units ?

  H = ¾ M = ½ L = ¼ F = very few Z = none
* and what **functions** are your members' current units performing during typical missions ('current' column on p.3) ?

RANGE OF CAPABILITIES

* IN-VEHICLE NAVIGATION/INFORMATION SYSTEMS *

TRAVEL ADVISORY
- road map
- traffic rules
- route guidance
- emergency response
- public service messages
- roadside/community services

FLEET MANAGEMENT
- position tracking – vehicle
- position tracking – shipment
- route modifications (P&D)
- security – vehicle
- security – cargo
- security – occupant

TRAFFIC MANAGEMENT
- street level control
- area wide traffic cntrl
- freeway traffic mgt
- vehicle access
- enforcement
- traffic data collection

MOBILE OFFICE
- word processing & computing
- communications
- freight management
- data base mgt – genrl reference
- data base mgt – en-route active
- home base control

VEHICULAR CONTROL
- vehicle monitoring
- vehicle control
- event recording
- robotic steering

OCCUPANT ACTIVITIES
- environmental data
- education & training
- personal references
- entertainment
- external communications

Comments:

FUNCTIONS PERFORMED

* IN-VEHICLE NAVIGATION/INFORMATION SYSTEMS *

functions performed	installations current	installations future
(over&above current options from veh manufacturers)	(H M L F Z)	
- record veh use statistics (km, fuel, hrs, ...)	___	H H
- record en-route events (replace manual log)	___	H M
- record/display engine diagnostics (tach+)	___	M M
& display trouble shooting instructions	___	___ L
- assist in driving functions (beyond tachograph) (eg. rear view on CRT, coll avoidance radar,..)	___	F H
- position vehicle on driver's map	___	L H
- position vehicle on dispatch map	___	M M
- position individual LTL shipments on dispatch map	___	H -
- redirect P&D during run - dispatch -> truck (one way)	___	Z Z
- fully inter-active	___	H L
- route guidance - veh position on map display only	___	Z L
(genrl & d.g.) - turn instructions to reach destn	___	L M
- turn instrns to avoid congestion	___	L H
- access control (automatic tolls, zone entry control)	___	M L
- traffic rules (turn restrictions, parking, loading, ...)	___	M L
- on-board data management and display		
- base inventory ROM (permits, d.g. instructions, ...)	___	H M
- en-route active collection (manual & automtc entry)	___	L Z
- reception of external data (&voice) batches	___	M L
- word processing & computing (& invoice printout, ...)	___	L- M
- communications - receiving only	___	___ -
- transmitting only	___	___ -
- both, as: simplex or duplex	___	H M
- vehicle <-> base	___	H M
- vehicle <-> company's other vehicles	___	L L
- vehicle <-> almost anywhere	___	Z L
- security - vehicle	___	H M
- cargo	___	H -
- occupant	___	M M
- yellow pages - operations specific (garages, ...)	___	Z L
- general	___	L L
- education & training	___	L M
- entertainment	___	L H
- personal references & memory pad	___	L+ M
- other _ _ _ _ _ _ _ _ _ _ _	___	___

* What have your members' experiences been with the current devices ?
  - overall impression _
  - specific +s and -s _

* What are the systems most used for:
  - as a planning tool (improve P&D path, schedules, ...)
  - monitor employee performance (schedule&task adherance, ..)
  - to facilitate: JIT / mobile EDI / FMIS / ...
  - customer relations: service predictability, early warning of delayed delivery, shpmnt position, ..
  - other: _

* As things stand now, when do you see these systems being:
  - experimented with _____
  - installed by your major operators _____
  - installed industry wide? _____

* In the future (say in 5 years), what functions are likely to stand out as important ?
  Codes (p.3): H = musts M = wants L = why-nots Z = no use

* What **characteristics**, do you feel, will be important in marketing these devices in the future (rate H/M/L/Z):

characteristics		characteristics	
* functionality	□	* communications capablty	□
- simplicity (to learn)	_	- simplex vs duplex	_
- ease in day-to-day use	_	- message retention	_
- ...	_	- channel capacity (for simultaneous users)	_
- ...	_		
* memory size for:	□	* 'looks'	□
- basic ROM pack	_	- design	_
- en-route accumulated	_	- technical	_
- electronic mail (in)	_	- ...	_
* input interface	□	* output interface	□
- keyboard/touchscr/..	_	- message line	_
- mouse/wand/..	_	- CRT screen	_
- voice	_	- buzer	_
- electronic i.d. card	_	- voice	_
-	_	- printer	_
* price (=life cycle cost)	□	* other	□
- purchase of unit	_	- accuracy	_
- instaltn & reinstltn	_	- reliability	_
- personnel training	_	- portability	_
- annual c&f&t insurance	_	- ...	_
- annual signal fee	_	- ...	_
- annual maintenance	_	- ...	_
- outside data updates	_	- ...	_
- up-keep of own data	_	- ...	_

Required Performance

Specific performance standard required, to be suitable for your typical member's application in day-to-day use:

	Inter-city	P&D + courr
* position accuracy (by service)		
- within a few metres + on correct street (and block) within city	—	—
- within a block either way (correct street, or one up/down) (ie. inside 4-6 blocks)	—	—
- within 1 km	—	—
- other: _____	—	—
* operational, in-use availability (by main feature)		
- equipment reliability [MTBF/(MTBF+MTR) mean failure + time to repair&reach repair ctr for in-veh&dispatch units]	Inter-city	P&D + courr
- max 1 hour off per month	—	—
- max ½-1 day off per month	—	—
- not critical (occasional 2-3 days off)	—	—
- position signal continuity [in the face of ext interferance (system otherwise working)]:		
- no disruptions (cont. positioning)	—	—
- ok to black out periodically 3-5 min	—	—
- not critical (occasional 10-20min ok)	—	—
- continuity of data&voice transmission [indicate if diffrnt for incoming vs. outgoing]		
- no disruptions (cont. transmition)	—	—
- ok to black out periodically 3-5 min	—	—
- not critical (occasional 10-20min ok)	—	—
- environmental robustness, against:		
- vibration & shock		—
- dust & grease		—
- coffee spills		—
- relative humidity		—
- temperature variations & max/min		—
- current level swings (battery&altrntr)		—
- RF environment		—
- pass compartment noise (reducing audibility at rear & preventing control by voice)		—
* portability		
- within vehicle: fixed vs. removable from housing		
- data pack (floppy disk, CD-ROM, ...)		—
- short distance peeper: from/to vehicle		—
- wand or mic (for reading in&out pallets)		—
- full lap unit: keyboard, crt, microprcssr, mouse		—

- useability once removed: ie. which features retained with internal powerpack and/or external connection (eg. data mgt, word proc, location signal, route guidance, data/voice transmission/reception, ...)
  - at another position within same vehicle ___
  - en-route (walking, another car, GoTrain, boat, plane) ___
  - inside home, office, hotel (compatibility: juice, LAN connections) ___
- carriability (weight & casing's convenience in hand)
  - short move (car-to-office or car-to-GoTrain) ___
  - long trek (exploration, forestry) ___

* agreeable **price** for each in-vehicle unit, of the type that you require (circle for two system options: bare & delux):
- bare bones (lifeline functions: _ _ _ _ _ _ _ _ _ _) _____
- delux (+goodies: _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _) _____

for reference:
- into how many vehicles in typical full implementation ___
- what does each vehicle cost: type 1 = _____
  type 2 = _____

note: plain GPS vehicle units have cost $4000-$6000; plain ETAKs $1500 (both requiring another 20-50ooo)

a. 10000± (6000-15000)
b. 4000± (3000- 5000)
c. 1500± (1000- 2000)
d. 700± (500-900)
e. 300± (200-400)

* minimum warranty period (parts & labour) _____

* max annual up-keep cost: _____
- annual collision/fire/theft insurance
- system access cost (location sgnl + data/voice signal)
- regular maintenance on the vehicle unit
- periodic data pack up-dates (probably one/year)
- new release of user software (probably one/2 years)
- up-keep of own data (incl training of new employees).

Barriers

* What are primary barriers (if any) to wide scale implementation within your industry ?
- such systems are not really needed ___
- functions currently offered do not meet requirements
  - not quite yet ___
  - not even close ___
- lack of human factors consideration
  - hardware: not secureable against theft, ... ___
    too many separate components, ... ___
    ergonomics (rips fingers), ... ___

- software: tedious to use, ... __
  not individualized, ... __
  other: _____ __
- general: lack of safety in use (when in motion) __

- management rigidity ("30-year men" don't change easy) __
- unions - general threat to privacy __
  - time keeping & devt of work perf standards __
- ...
- true life-cycle cost (counting everything) __

* Can you think of some ways of ameliorating these barriers (whether real or perceived) ?

Future Needs

* What are your members' immediate needs in this mobile information systems/navigation field; what would be helpful:
  - conference of users (direct & indirect), suppliers and regulators ?
  - state-of-the-art summary pamphlet, which is updated twice yearly, readily available (subscriptions, .) and contains:
    - equipment illustrations, specs, layman's summaries __
    - list prices (for 1, 10, 100 unit purchases) __
    - supplier names - hardware / software __
      - data: ready made/one-of-the-kind __
    - topical discussions on - strengths & weaknesses __
      - licencing & regulation __
      - etc: _ _ _ _ _ _ _ _ _ __
  - other: __
    __

Name

Title

Association

Street

City, Province

Country ZipCode

Tel: (...) ...-....

Current membership: corporate =
individual =

Request: brochure / membership list (by category) /
paper summarizing association's related work

APPENDIX F

STANDARDS FOR MARINE CARTOGRAPHY

* SELECTED NOTES ON ACTIVITIES *

STANDARDS FOR MARINE CARTOGRAPHY

SELECTED NOTES ON ACTIVITIES

The **Canadian Hydrographic Service**/Department of Fisheries and Oceans is involved with several organizations developing standards for marine cartography which will have a bearing on the landside as well:

North Sea Hydrographic Organization (NSHO)

* planning a series of short term trials called 'North Sea Electronic Test Bed' (Fall 88):
  - manufacturers will provide electronic chart systems/ prototypes and data in standard format
  - on-board installation will include: micro-computer & antenna & interface to GPS and Loran-C & gyro-compass & may be radar
  - trials will be held in various harbours in Norway to demonstrate that the system works (approach similar to earlier Canadian trials in Halifax by Fredericton company, Universal Systems Ltd)
  - updating aspect will be tested via floppy disk which will provide an over-ride for the display (this will not yet be electronically transmitted from shore)
* NSHO's earlier preference, CEDD format, has been dropped from the trials (required modifications would have been too tedious)
* Canada is planning to participate in the demonstration.

International Hydrographic Organization (IHO)

* mission: coordinate and standardize activities in hydrography and sea navigation (chart/hydrographic standards)
  - International Hydrographic Bureau located in Manaqua
* Committee for Exchange of Digital Data (IHO CEDD)
  - proposal from 2 years ago for standards, called "CEDD Format", appears likely to die:
    - not that good (was the only one around, so it got adopted)

- there is no secretariat looking after and updating /refining CEDD

International Marine Organization (IMO)

* dictates the laws, rules and formats (radio frequency spectrums, etc) that countries agree to follow
* located in Europe (most meetings in London) & works with IHO

Radio Technical Commission for Maritime Services

* RTCM, which is related to IMO, is located in the U.S.
* mission: electronic charting design and specification & IMERSAT (satellite services for the marine sector)

National Ocean Service (NOS)

* U.S. equivalent to Canadian Hydrographic Service

Applications at Sea (general comments):

* the sea world is quite different (organizationally, politically and practically) from the land side, eg:
  - when the weather is perfect, systems are not needed
  - when the weather is hostile and the equipment is failing one can not 'stop and stay overnight at a waveside motel'
    -> the result: both philosophy and approach are quite different, even though technology is shared
* land based systems usually apply within one country, whereas sea world is international (except for coastal fishing and recreational boating)
  note: Prometheus, and the whole Eureka platform, <u>are</u> international
* the shear number of applications of mapping and navigation technologies on the land side will drive down the cost, thereby making them available to the sea world more widely
* traditional conventions are hard to get away from, even where electronics would make things more efficient, ie. there is a tendency to copy past manuals and paper chart techniques

* there are many hurdles yet to overcome, which will take years to evolve, eg:
  - MACDIF, when it finally is fully operational for charts, is only a channel between data bases - but the existing data bases are quite different and some of them rather 'cock-eyed' (ie. MACDIF focus is at the digitizing end, whereas the fundamentals of electronic charts are still evolving)
  - MACDIF is not yet quite fully developed, to make it possible to request detailed comment from European counterparts; however, workshops are planned for Canada, Holland and U.S.

The **Mapping and Charting Establishment**/Department of National Defence is involved in the development of cartography and navigation standards for the ground, sea and air sectors internally as well as through its activities within NATO:

DEFENCE MAPPING AGENCY (Canada)

* product specifications for digitized raster graphics (DRG) - 2nd draft by DMA Systems Center of St.Louis, Missouri (15 Dec 87) - contains:
  - introduction / analog-to-digital conversion / product format (DRG file description & format specs) / distribution media (magnetic tape & WORM)
* product specifications for ARC digitized raster graphics (ADRG) - 2nd draft by DMA (15 Dec 87)
  - ARC = DRG image is transferred to a universal frame of reference, the Equal **A**rc-Second **R**aster **C**hart/Map projection system, so that each pixel represents a geographic entity of latitude and longitude
* digital geographic information exchange standards - final draft by geographic information working group (DGIWG) (Oct 87) - contains:
  - scope & purpose & field of application and general concept
  - specifications: media, header record, data exchange structures, feature/attribute coding, data quality
  - exchange format implementation rules: files & sections & records, delimiters & symbols, special symbols, attribute & relation coding, topological exchange format.

NATO

* Military Agency for Standardization (MAS) is considering separate standardization agreements for air, land, and water:
  - Interservice Geographic Working Group is focusing on:
    - any standardization agreement that deals with geographic data organization (groups & sub-groups), quality, specifications and features
* Digital Geographic Information Working Group (DGIWG)
  - mission: formulate a standard (prior to the massive hierarchy of NATO) in the hopes of introducing it successfully to NATO itself
* CERCO = (abbreviation of french name for a European standardization effort)
* comment: so many people, so many committees that the process may go on forever -> MACDIF, based on ISO communication standards, may or may not be able to penetrate all the way through that bureaucratic maze

Others

National Advisory Council on Canadian Surveyors on Mapping (NACCSM)

MSAT Program / Industry and Economic Development / Government Telecommunications Agency / Department of Communications

MSAC Administration / Board on Earth Sciences / Commission on Physical Sciences, Mathematics and Resources / National Academy of Sciences

Committee Advisory to the U.S. Geological Survey on Mapping Science - refer to SAE Navigation Sub-Committee/October 1987 minutes (letter from consultant)

Research & Development One / U.K. Ordnance Survey: developing a national transfer format - refer to article by A.B. Smith

International Electrotechnical Commission (IAC)

Additional information not contained in these appendices is available on request to The Editor.

This information includes:

1. Ontario Communications Handbook–Table of Contents
2. Contact List–Description of Header Record
3. List of Associations–Representatives of Potential User Communities
4. Ontario Trucking Industry Survey for WAVM Applications
5. List of Canadian Companies–With R&D Capabilities Related to Mobile Information Systems